PROP TO PILOT

A HANDBOOK FOR PILOTS

HAMILTON STANDARD PROPELLERS
DIVISION OF UNITED AIRCRAFT CORPORATION, EAST HARTFORD, CONNECTICUT

Here's the root of the situation. The propeller is supposed to propel the plane forward fast enough to enable its wings to lift and support it clear of the earth.

However, aviators were stumped when they discovered the propeller got them clear of the earth but needed a change to a higher blade pitch in order to keep its good grip on the faster moving air in high speed, level flight. If the pitch couldn't be changed, the entire rig was up a tree.

Hamilton Standard Propellers fixed this situation by making the "gear shift of the air" — a two position prop that permitted an aviator to change from a low pitch necessary for take-off to a high pitch for level flight.

For the pilot to enjoy the benefits of high pitch, high speed flight had to be maintained. But this was very tiring, and some of the boys got "bushed".

So, Hamilton Standard cured this by developing the Hydromatic (constant speed) prop, which permitted a full range of pitch positions between the low pitch for take-off and the high pitch settings. This made it possible to operate the propeller at its most efficient angle of blade pitch at all air speeds and RPM settings—

All automatic too—just set the prop to a desired RPM of the engine, and there the RPM would stay whether the plane was climbing, cruising or diving.

This made everything very, very efficient.

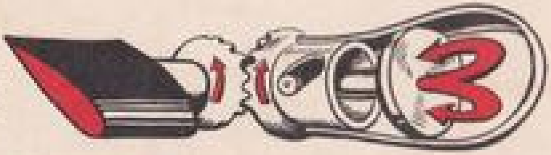
EVERYBODY WAS HAPPY.

The method used by Hamilton Standard Propellers to change the prop pitch is an hydraulically operated piston that pushes or pulls on a cam connected to gears on the prop blades.

The cam action that turns the gears is very similar to that of the automatic screw driver.

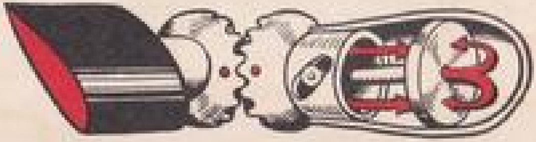
In the Hydromatic prop, oil pressure is the driving force that moves the piston in the direction desired to change the blade pitch. Assuming constant power and RPM:

PROP SHOWN GOING INTO HIGH PITCH.



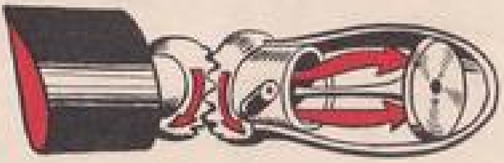
HIGH PITCH WILL BE USED FOR HIGH AIR SPEEDS AS IN LET DOWN OR HIGH ALTITUDE FLIGHT.

PROP SHOWN HOLDING A **MEDIUM PITCH** POSITION.



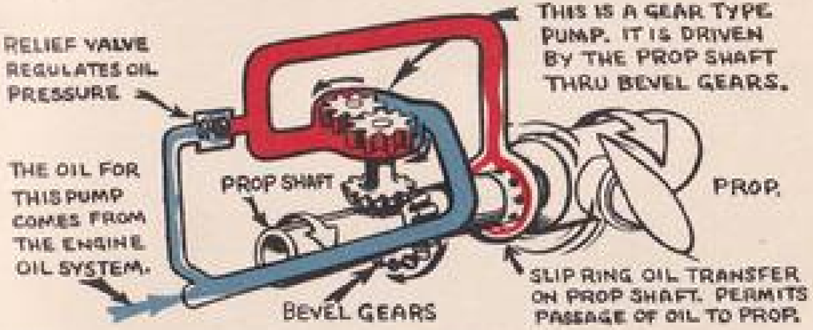
OIL UNDER PRESSURE IS METERED TO MAINTAIN A BALANCED CONDITION. MEDIUM PITCH IS FOR MEDIUM SPEEDS AS FOR CRUISING.

PROP SHOWN GOING INTO **LOW PITCH.**

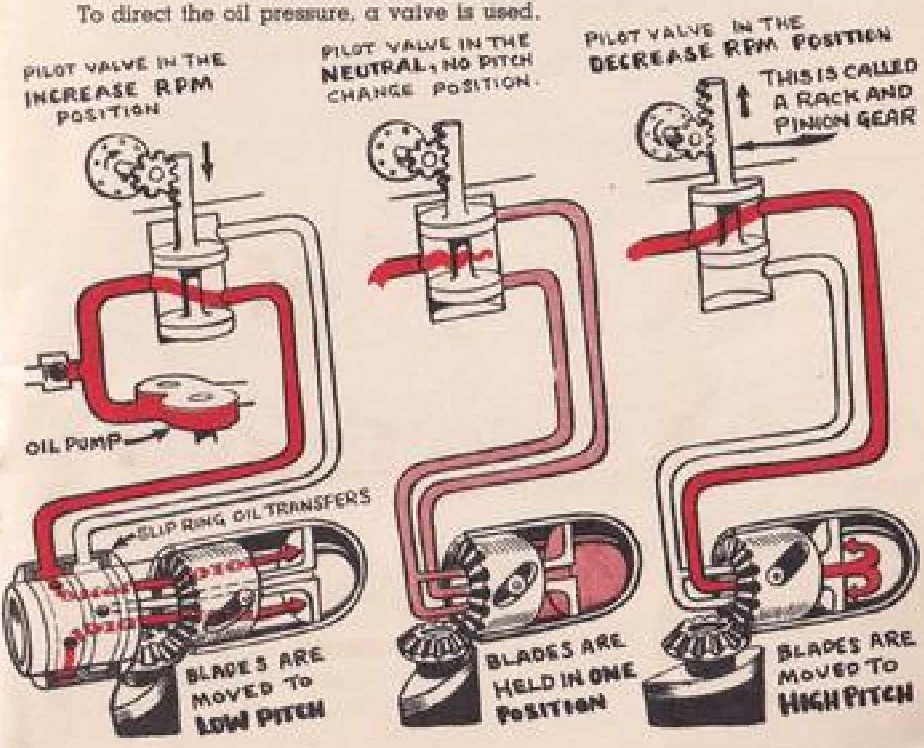


LOW PITCH WILL BE USED FOR LOW AIR SPEEDS AS IN A CLIMB OR TAKE-OFF.

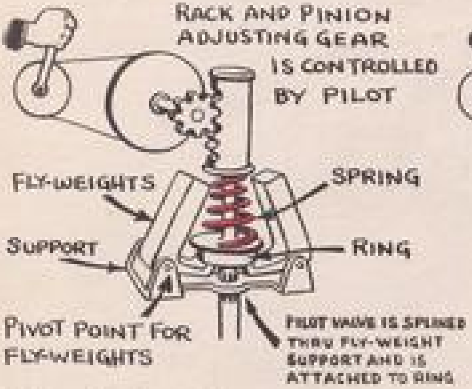
To develop high oil pressures for insuring positive and quick prop action, a pump is used.


THIS IS A GEAR TYPE PUMP. IT IS DRIVEN BY THE PROP SHAFT THRU BEVEL GEARS.
RELIEF VALVE REGULATES OIL PRESSURE
THE OIL FOR THIS PUMP COMES FROM THE ENGINE OIL SYSTEM.
PROP SHAFT
PROP.
BEVEL GEARS
SLIP RING OIL TRANSFER ON PROP SHAFT. PERMITS PASSAGE OF OIL TO PROP.

To direct the oil pressure, a valve is used.

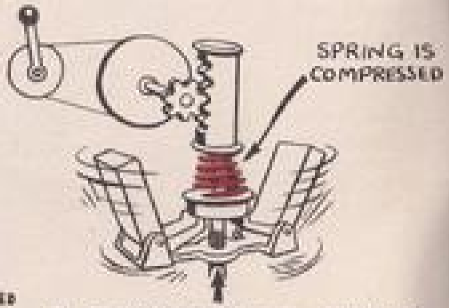

PILOT VALVE IN THE INCREASE RPM POSITION
PILOT VALVE IN THE NEUTRAL, NO PITCH CHANGE POSITION.
PILOT VALVE IN THE DECREASE RPM POSITION
THIS IS CALLED A RACK AND PINION GEAR
OIL PUMP
SLIP RING OIL TRANSFERS
BLADES ARE MOVED TO LOW PITCH
BLADES ARE HELD IN ONE POSITION
BLADES ARE MOVED TO HIGH PITCH

To relieve the pilot of constantly attending to the **PILOT VALVE** to maintain **CONSTANT SPEED** of the engine, a **GOVERNOR** driven by the engine is used . . .

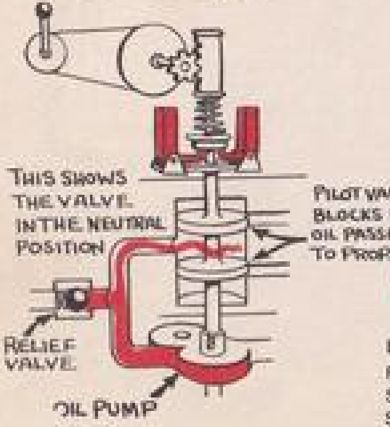

RACK AND PINION ADJUSTING GEAR IS CONTROLLED BY PILOT
FLY-WEIGHTS
SPRING
SUPPORT
RING
PIVOT POINT FOR FLY-WEIGHTS
PILOT VALVE IS SPLINED THRU FLY-WEIGHT SUPPORT AND IS ATTACHED TO RING

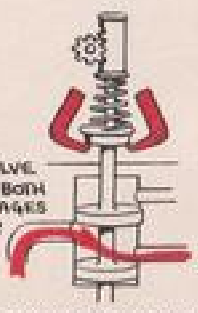
This is the fly-weight arrangement. It is a centrifugal type.

The **FLY-WEIGHTS** are joined to the **PILOT VALVE**, so that the latter will be in a neutral position when the fly-weights are upright.

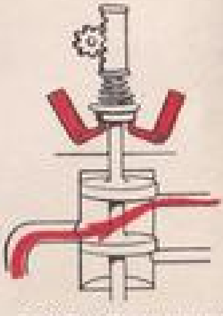


If the fly-weights are rotated by the engine, centrifugal force makes them fly outward, thus lifting the ring on which the spring sets, and the ring lifts the pilot valve. The faster the fly-weights are rotated, the further out they fly, and the more they lift the pilot valve against the load on the spring.


THIS SHOWS THE VALVE IN THE NEUTRAL POSITION
PILOT VALVE BLOCKS BOTH OIL PASSAGES TO PROP
RELIEF VALVE
OIL PUMP



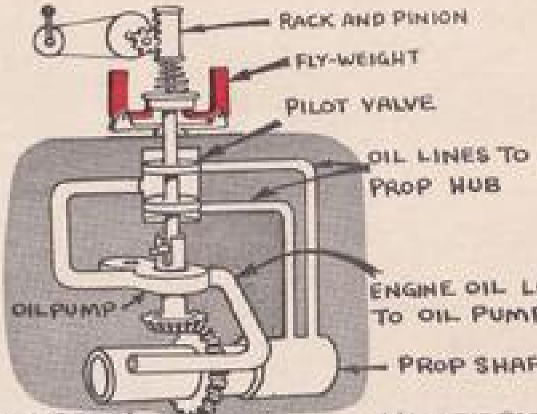
BELOW NEUTRAL POSITION
FLY-WEIGHTS TURNING TOO SLOW FOR LOAD ON SPEEDER SPRING.

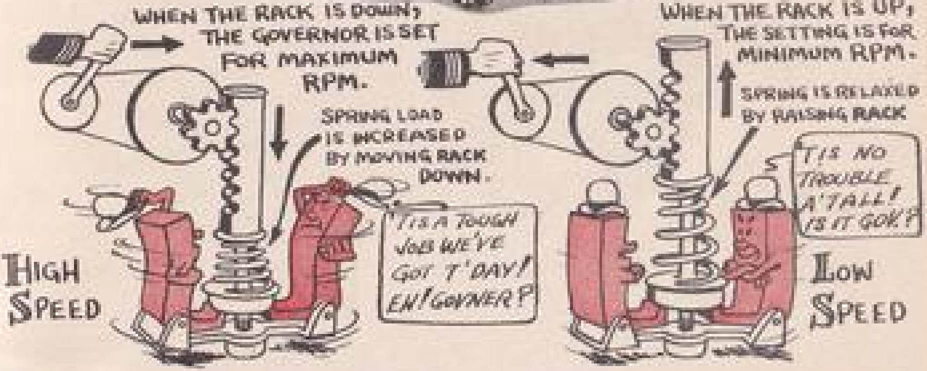


ABOVE NEUTRAL POSITION
FLY-WEIGHTS TURNING TOO FAST FOR LOAD ON SPEEDER SPRING.

The **fly-weights** are rotated directly by the **prop shaft** through the **gear pump.**

This sketch shows the rack and pinion, the fly-weights, the pilot valve and the oil pump assembled in one unit called the **GOVERNOR.** In actual operation the pilot valve is not driven or connected to the gear pump as shown.

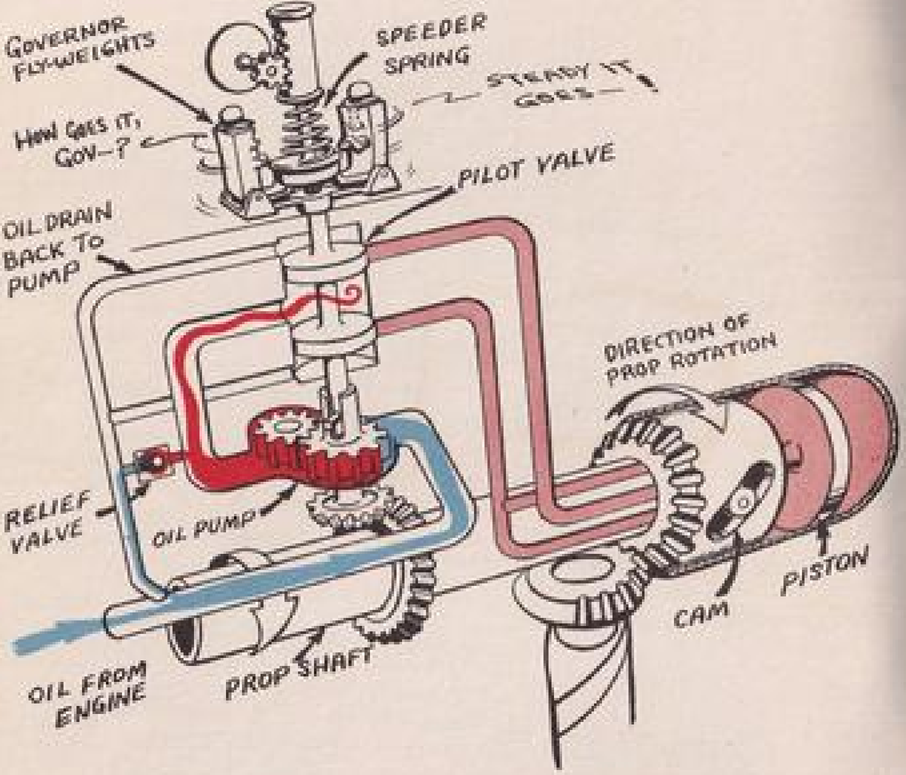



WHEN THE RACK IS DOWN; THE GOVERNOR IS SET FOR MAXIMUM RPM.
SPRING LOAD IS INCREASED BY MOVING RACK DOWN.
'TIS A TOUGH JOB WE'VE GOT T'DAY! EH! GOVNER?
HIGH SPEED
WHEN THE RACK IS UP; THE SETTING IS FOR MINIMUM RPM.
SPRING IS RELAXED BY RAISING RACK
'TIS NO TROUBLE A'TALL! IS IT GOV?
LOW SPEED

The governor is designed to permit the pilot to change the spring load through the rack and pinion gear. If the pilot loads the spring, the fly-weights will have to be driven faster by the engine to make them fly outward against the greater spring load. A high RPM setting is obtained in this manner.

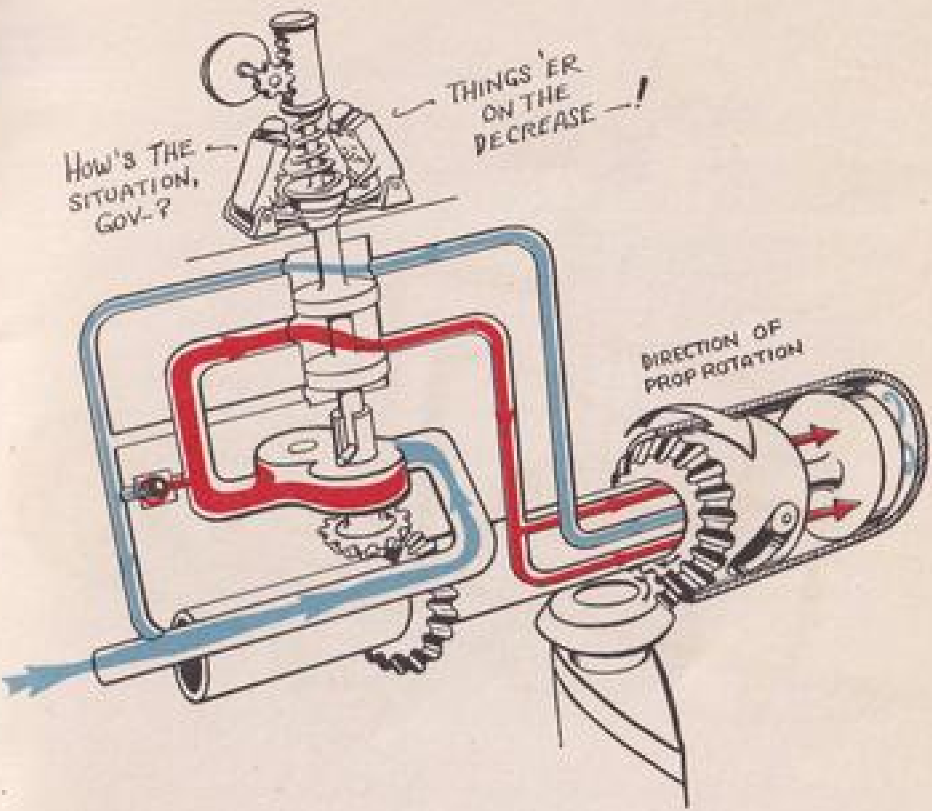
If the pilot relaxes the load in the spring, the fly-weights will fly outward with ease, so they will have to be rotated only slowly to match the load of the speeder spring. This condition results in low RPM's.

Because the spring setting determines how fast the fly-weights have to be turned to position the pilot valve, the spring is called the **SPEEDER SPRING.**



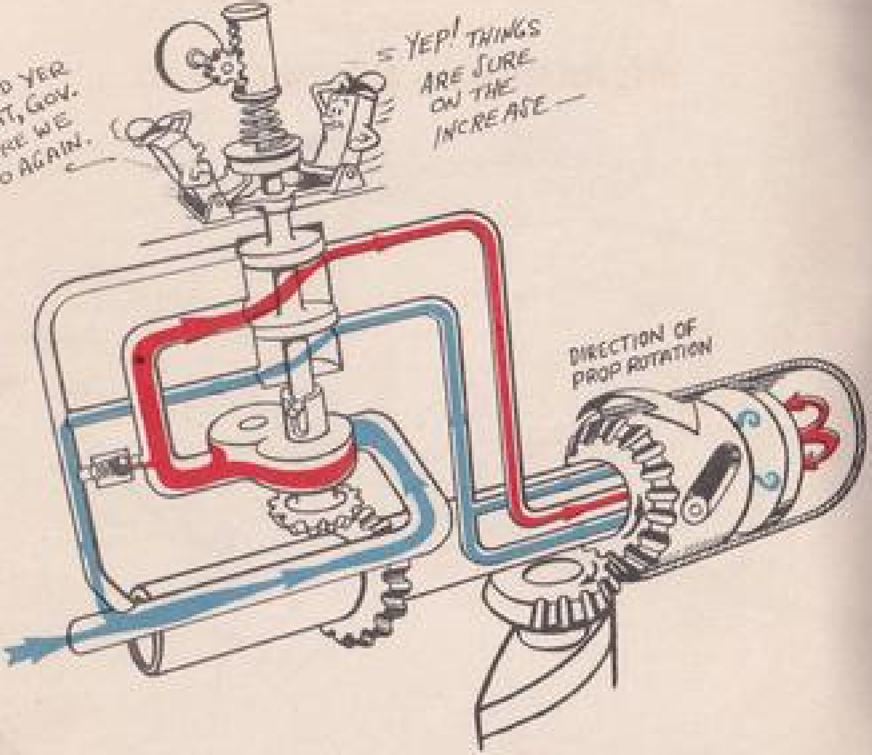
ON-SPEED (RPM remains steady)

This condition exists when the airspeed, altitude and engine power of the airplane are constant. The speeder spring has been set by the pilot for the RPM desired. The fly-weights moved the pilot valve which directed oil to the piston in the hub. This, in turn, moved the prop blades until they found a pitch that absorbed the engine power at the RPM selected by the pilot. When that moment of speed balance occurred, the forces of the fly-weights balanced the speeder spring load and positioned the pilot valve in the neutral, or constant speed, position.


HOW'S THE SITUATION, GOV.-?
THINGS 'ER ON THE DECREASE —!
DIRECTION OF PROP ROTATION

UNDERSPEED (RPM decreases)

This condition results if the plane should start to climb from level flight, and the prop pitch becomes too high due to a reduction in airspeed while the power remains unchanged. In order to keep the prop turning at the same RPM while its pitch has been effectively increased, more power is required from the engine. However, as the engine power remains the same, the higher pitch in the climb will cause the engine to slow down, thus causing underspeeding. This makes the fly-weights droop, moving the pilot valve in the position shown above. Oil then flows to the inboard side of the piston. The resulting action twists the blades to a lower pitch, automatically increasing the speed of the engine to the former RPM setting.


HOLD YER HAT, GOV. HERE WE GO AGAIN.
YEP! THINGS ARE SURE ON THE INCREASE —
DIRECTION OF PROP ROTATION

OVERSPEED (RPM increases)

This condition results, for example, when a let-down is started causing an increase in airspeed while still using the same power output from the engine. When the airspeed increases, the pitch setting, in effect, becomes too low. Therefore, it requires less power to turn the prop. The engine is still developing the same power, so it starts to overspeed. This will cause the fly-weights to spread out, thus lifting the pilot valve, so that oil flow is routed to the front side of the piston in the dome. The piston pushes the cam which, in turn, twists the blades to higher pitch. The engine speed slows down to its former RPM setting.

PILOT CONTROL of the GOVERNOR
by means of a
MECHANICAL or ELECTRIC HEAD.

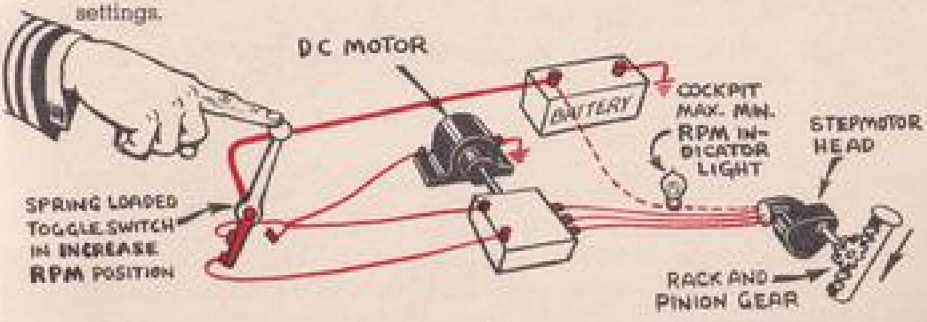
The mechanical control system to the governor consists of a pilot's lever in the cockpit that is connected to the governor rack and pinion gear through either cables and pulleys or push-pull rods.

The mechanical control system has certain limitations in large multi-engine aircraft where the distance from cockpit to governor is considerable, and the flexibility of the plane's structure may not allow satisfactory connections.

To surmount this difficulty, Hamilton Standard Propellers uses an ELECTRIC STEPMOTOR HEAD GOVERNOR CONTROL.

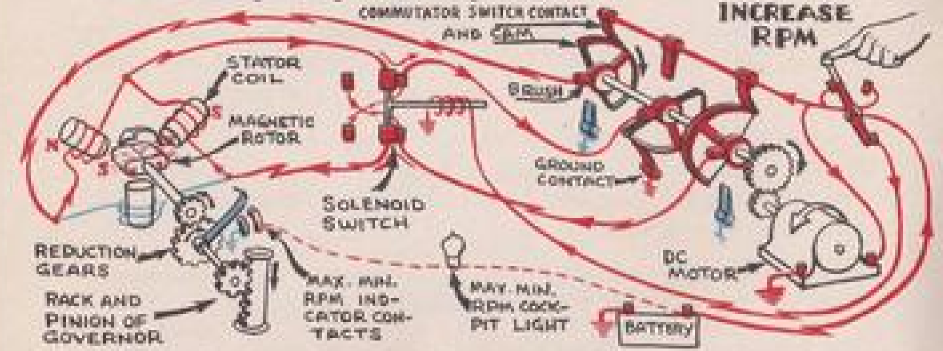
This is rugged, reliable and simple to operate. It consists of a toggle switch in the cockpit, a DC motor, and commutator switch located in the airplane, and a stepmotor which is hooked to the rack and pinion gear on the governor. The toggle switch energizes the DC motor and determines the direction of the stepmotor to increase or decrease RPM. The DC motor, through an 11 to 1 reduction gear, turns the commutator switch which energizes the stepmotor head. This is the equipment needed for each propeller.

Just push the toggle switch forward for INCREASE RPM or back for DECREASE RPM until the desired tachometer reading is obtained. An indicator light in the cockpit will show maximum and minimum RPM settings.

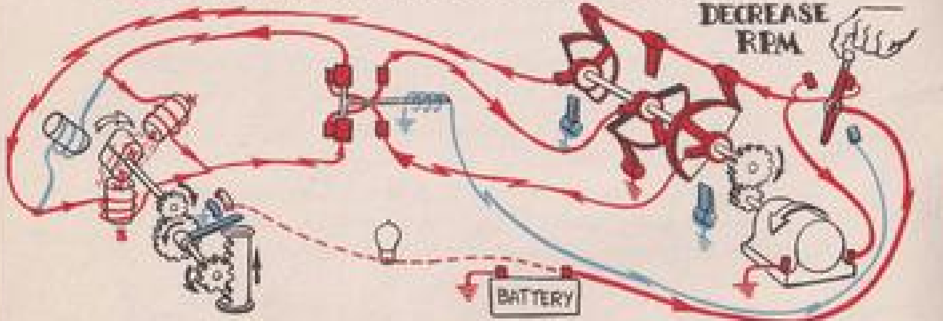

D C MOTOR
BATTERY
COCKPIT MAX. MIN. RPM INDICATOR LIGHT
STEPMOTOR HEAD
SPRING LOADED TOGGLE SWITCH IN INCREASE RPM POSITION
RACK AND PINION GEAR

The electric STEPMOTOR HEAD and COMMUTATOR SWITCH work in the following manner:

The stepmotor consists of three stator coils that are electrically magnetized and a permanently magnetized rotor. The stator coils are magnetized in sequence of "steps" by a commutator switch which causes the rotor to follow in steps. The rotor is geared to the rack and pinion gear of the governor.

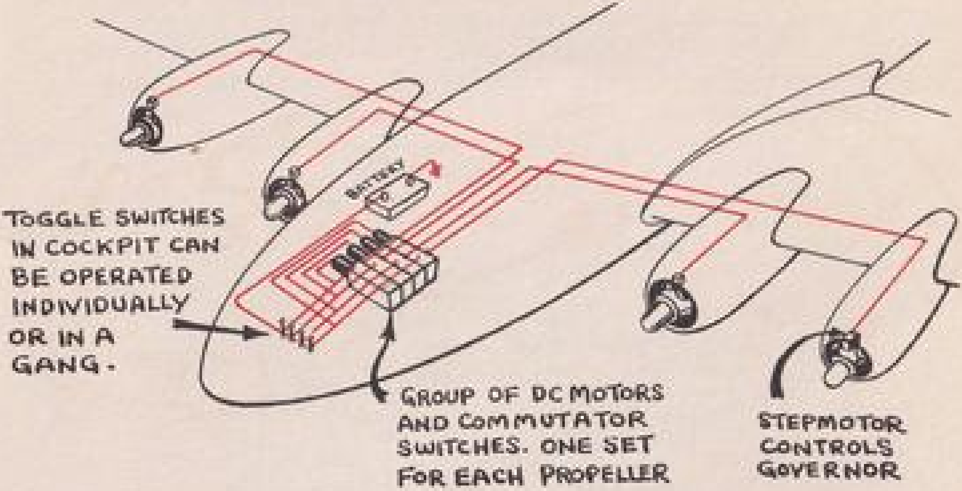

COMMUTATOR SWITCH CONTACT AND CAM
INCREASE RPM
STATOR COIL
N
S
MAGNETIC ROTOR
BRUSH
GROUND CONTACT
SOLENOID SWITCH
REDUCTION GEARS
RACK AND PINION OF GOVERNOR
MAX. MIN. RPM INDICATOR CONTACTS
MAX. MIN. RPM COCKPIT LIGHT
BATTERY
DC MOTOR

The north and south poles of the stator coils reverse when the current flow is reversed. The commutator switch and the toggle switch determine the direction of flow. The rotor turns to line up its magnetic field with those of the stator coils. When the toggle switch is in the increase RPM position, it energizes the DC motor, commutator switches, and the solenoid switch. The solenoid switch directs current flow to turn the rotor for increase RPM.



Moving the toggle switch to decrease RPM breaks the circuit to the solenoid switch, thus directing current flow to turn the rotor in a decrease RPM direction. Neutral position of the toggle switch shuts off the stepmotor system, except the indicator light, and the rotor acts as a magnetic brake for the rack and pinion.

Installation diagram of the Hamilton Standard electric stepmotor head system.


BATTERY
TOGGLE SWITCHES IN COCKPIT CAN BE OPERATED INDIVIDUALLY OR IN A GANG -
GROUP OF DC MOTORS AND COMMUTATOR SWITCHES. ONE SET FOR EACH PROPELLER
STEPMOTOR CONTROLS GOVERNOR

The outstanding feature of this system is that in case of partial or complete failure of the electric system, the propellers continue operating under the constant speed control of their governors at the RPM used at the time of the electrical failure. This safety feature can best be explained by an example:

> An airplane is cruising at 23,000 feet at 260 mph true airspeed. At 2050 RPM and 33 inch MP the prop pitch at this power setting and airspeed will be quite high. If at these conditions the electrical system of the airplane should fail, automatically, all stepmotors are magnetically locked, but the governors are still free to provide constant speed operation of the propellers.
>
> As the pilot slows the ship down for a landing, he is unable to change the RPM setting of the engines, but the propeller is still able to lower its pitch for the slower airspeeds required for approach.

PROP FEATHERING

Aviators were well satisfied with the constant speed prop until they started flying larger, higher performing aircraft of two or more engines.

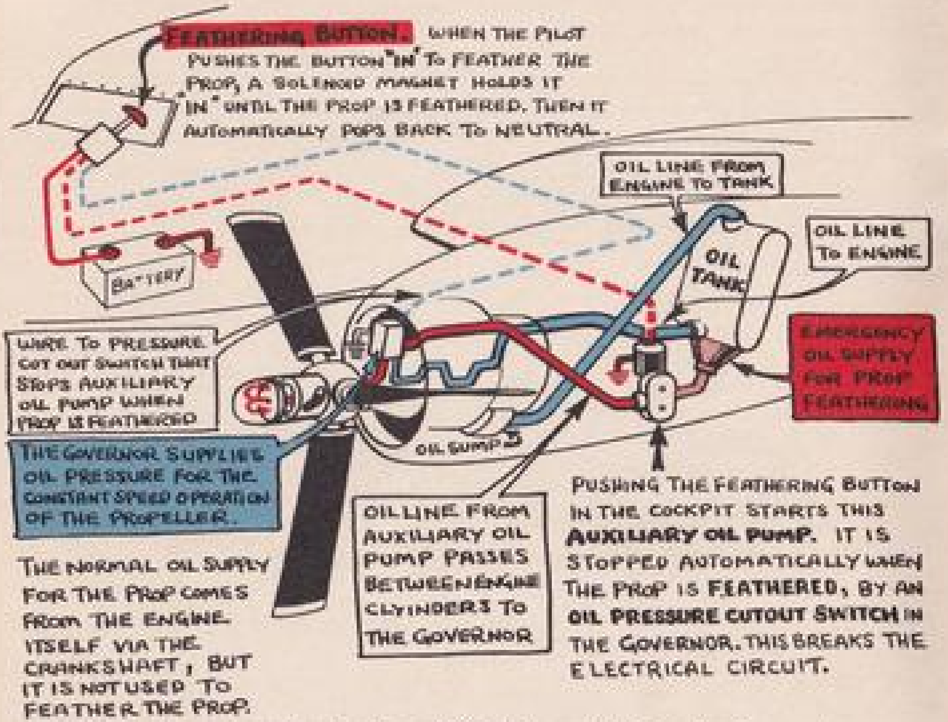
They found that if any one of the engines failed to put out power in flight, its windmilling propeller caused a great upset in control, a loss of performance, possibly further damage to the inoperative engine and excessive aircraft vibration.

DON'T STOP NOW!
BUT, I GOT A BLISTER!
YIP!

Hamilton Standard Propellers figured out a way to feather the prop, so that the windmilling propeller could be brought to a stop, and the "drag" reduced to a minimum.

NOW HE WOULDN'T CARE IF I BROKE AN ARM.

This is a rough idea of the **Feathering System** for a propeller installation.



FEATHERING BUTTON. WHEN THE PILOT PUSHES THE BUTTON "IN" TO FEATHER THE PROP, A SOLENOID MAGNET HOLDS IT "IN" UNTIL THE PROP IS FEATHERED. THEN IT AUTOMATICALLY POPS BACK TO NEUTRAL.

OIL LINE FROM ENGINE TO TANK

OIL LINE TO ENGINE

EMERGENCY OIL SUPPLY FOR PROP FEATHERING

WIRE TO PRESSURE CUT OUT SWITCH THAT STOPS AUXILIARY OIL PUMP WHEN PROP IS FEATHERED

THE GOVERNOR SUPPLIES OIL PRESSURE FOR THE CONSTANT SPEED OPERATION OF THE PROPELLER.

OIL LINE FROM AUXILIARY OIL PUMP PASSES BETWEEN ENGINE CLYINDERS TO THE GOVERNOR

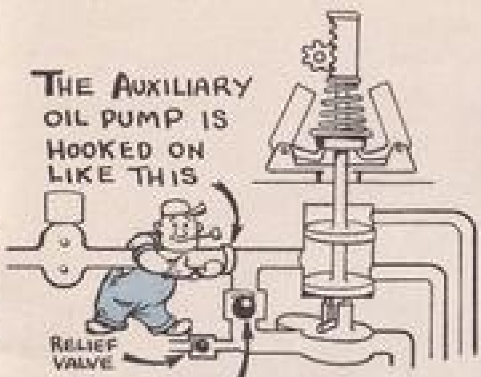
PUSHING THE FEATHERING BUTTON IN THE COCKPIT STARTS THIS **AUXILIARY OIL PUMP.** IT IS STOPPED AUTOMATICALLY WHEN THE PROP IS **FEATHERED,** BY AN **OIL PRESSURE CUTOUT SWITCH** IN THE GOVERNOR. THIS BREAKS THE ELECTRICAL CIRCUIT.

THE NORMAL OIL SUPPLY FOR THE PROP COMES FROM THE ENGINE ITSELF VIA THE CRANKSHAFT, BUT IT IS NOT USED TO FEATHER THE PROP.

The prop governor had to be modified to handle this feathering and unfeathering oil system.

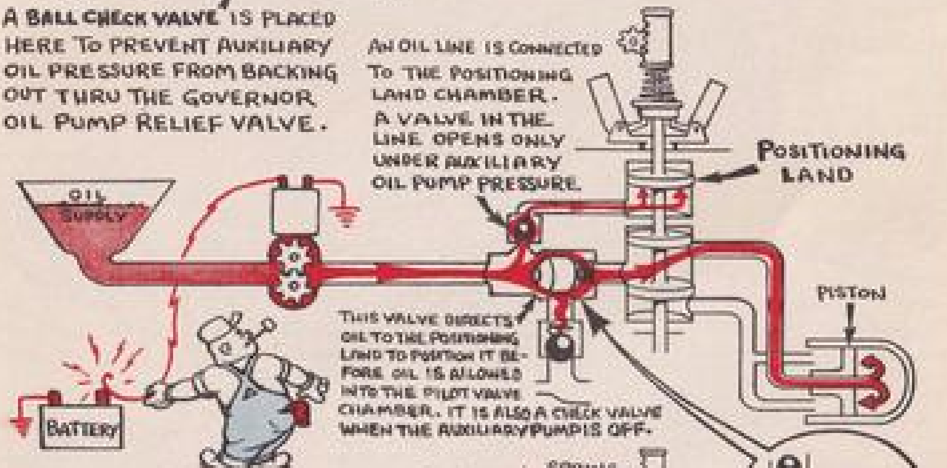
First, the oil line from the feathering pump had to be brought into the valve chamber of the governor.

WHERE DO I PUT IT, GOVERNOR?
RIGHT THERE, MY GOOD MAN—
AUXILIARY OIL PUMP
PILOT VALVE CHAMBER
GO

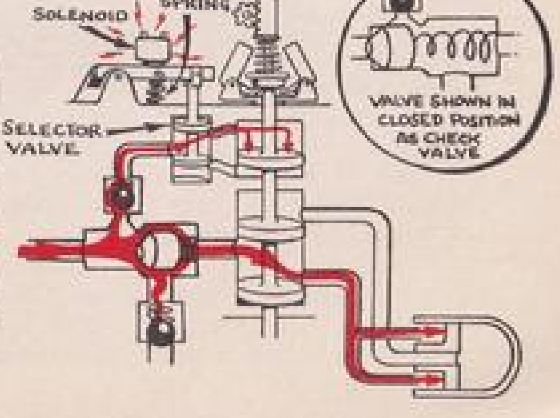

THE AUXILIARY OIL PUMP IS HOOKED ON LIKE THIS
RELIEF VALVE
A BALL CHECK VALVE IS PLACED HERE TO PREVENT AUXILIARY OIL PRESSURE FROM BACKING OUT THRU THE GOVERNOR OIL PUMP RELIEF VALVE.

However, the pilot valve may not be in the proper position to direct the oil to the outboard side of the piston.

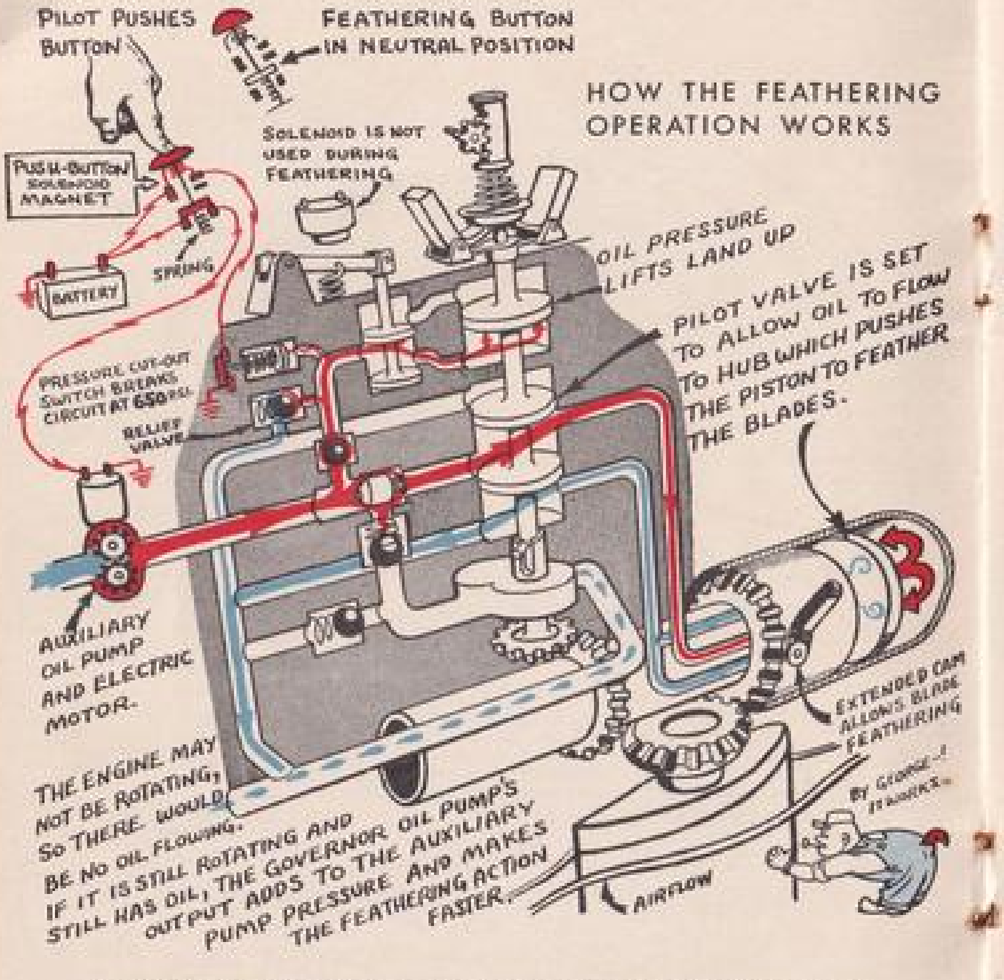
To be sure the pilot valve is lifted to the up position, a positioning land is used which, by means of oil pressure, lifts the pilot valve.


AN OIL LINE IS CONNECTED TO THE POSITIONING LAND CHAMBER. A VALVE IN THE LINE OPENS ONLY UNDER AUXILIARY OIL PUMP PRESSURE.
POSITIONING LAND
OIL SUPPLY
PISTON
THIS VALVE DIRECTS OIL TO THE POSITIONING LAND TO POSITION IT BEFORE OIL IS ALLOWED INTO THE PILOT VALVE CHAMBER. IT IS ALSO A CHECK VALVE WHEN THE AUXILIARY PUMP IS OFF.
BATTERY
VALVE SHOWN IN CLOSED POSITION AS CHECK VALVE

The positioning land is also used in unfeathering the prop, so it has an oil line hooked to the opposite side of its chamber. Oil pressure pushes the "land" and the pilot valve down. A selector valve, controlled by a solenoid and a spring, is installed to permit directing oil to either side of the positioning land.



HOW THE FEATHERING OPERATION WORKS


PILOT PUSHES BUTTON
FEATHERING BUTTON IN NEUTRAL POSITION
PUSH-BUTTON SOLENOID MAGNET
BATTERY
SPRING
SOLENOID IS NOT USED DURING FEATHERING
OIL PRESSURE LIFTS LAND UP
PILOT VALVE IS SET TO ALLOW OIL TO FLOW TO HUB WHICH PUSHES THE PISTON TO FEATHER THE BLADES.
PRESSURE CUT-OUT SWITCH BREAKS CIRCUIT AT 650 P.S.I.
RELIEF VALVE
AUXILIARY OIL PUMP AND ELECTRIC MOTOR.
3
EXTENDED CAM ALLOWS BLADE FEATHERING
THE ENGINE MAY NOT BE ROTATING, SO THERE WOULD BE NO OIL FLOWING.
IF IT IS STILL ROTATING AND STILL HAS OIL, THE GOVERNOR OIL PUMP'S OUTPUT ADDS TO THE AUXILIARY PUMP PRESSURE AND MAKES THE FEATHERING ACTION FASTER.
AIRFLOW
BY GEORGE J. FRANKS

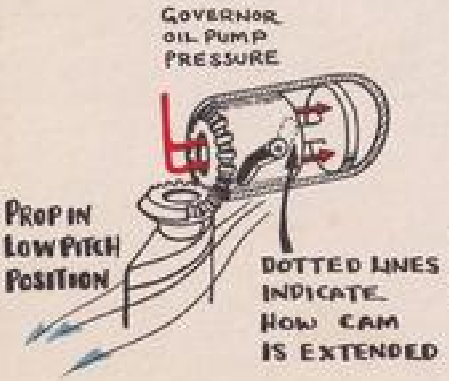
TO FEATHER THE PROP, the pilot pushes the feathering button. This starts the auxiliary oil pump. Its high pressure oil flows through to the positioning land and lifts it up, thus positioning the pilot valve. The feathering button is held in the "down" position by a solenoid magnet. When the prop is fully feathered, oil pressure builds up, "kicking out" the pressure cut-out switch and breaking the circuit to the push-button solenoid. The feathering button "pops" back to neutral, thus shutting off the auxiliary pump.

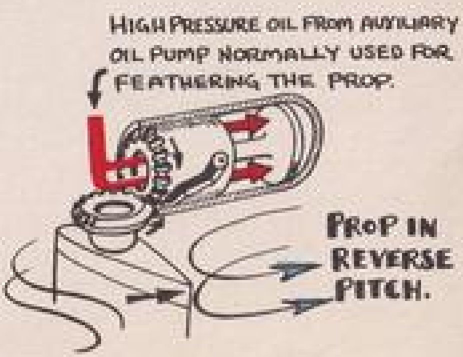
PROP REVERSING

It wasn't long before aviators wanted to use the power of their engines to stop their planes on the ground.

REVERSE - TURN 'EM BACKWARDS.
WELL, I'M NOT SHUFFLIN' OFF T' BUFFALO!

This meant either reversing the engines, or changing the pitch of the propeller. Well, reversing the pitch of the Hamilton Standard propeller by hydraulic action is accomplished quite simply by extending the cam on the outboard end. The auxiliary oil pump of the feathering system is used to help the governor oil pump twist the blades into reverse pitch. So, why reverse the engine?

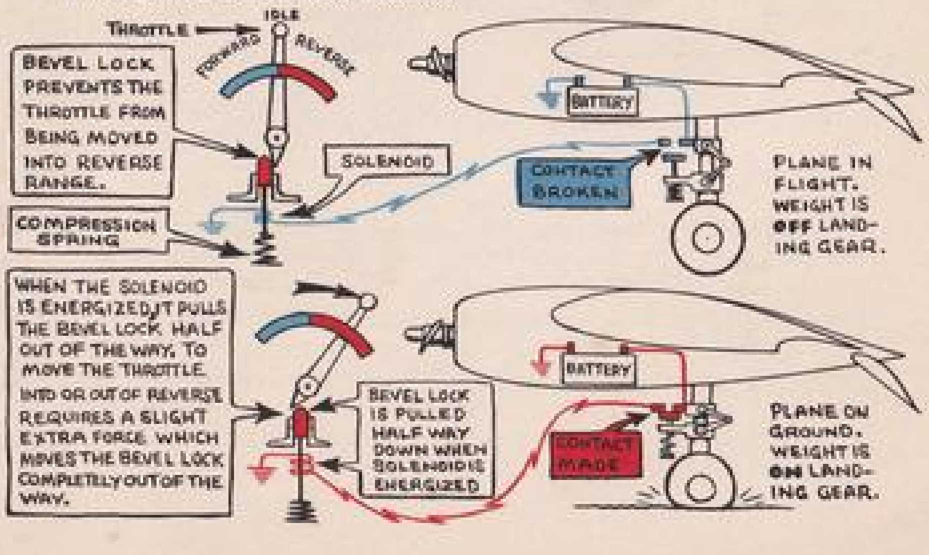

GOVERNOR OIL PUMP PRESSURE
PROP IN LOW PITCH POSITION
DOTTED LINES INDICATE HOW CAM IS EXTENDED


HIGH PRESSURE OIL FROM AUXILIARY OIL PUMP NORMALLY USED FOR FEATHERING THE PROP.
PROP IN REVERSE PITCH.

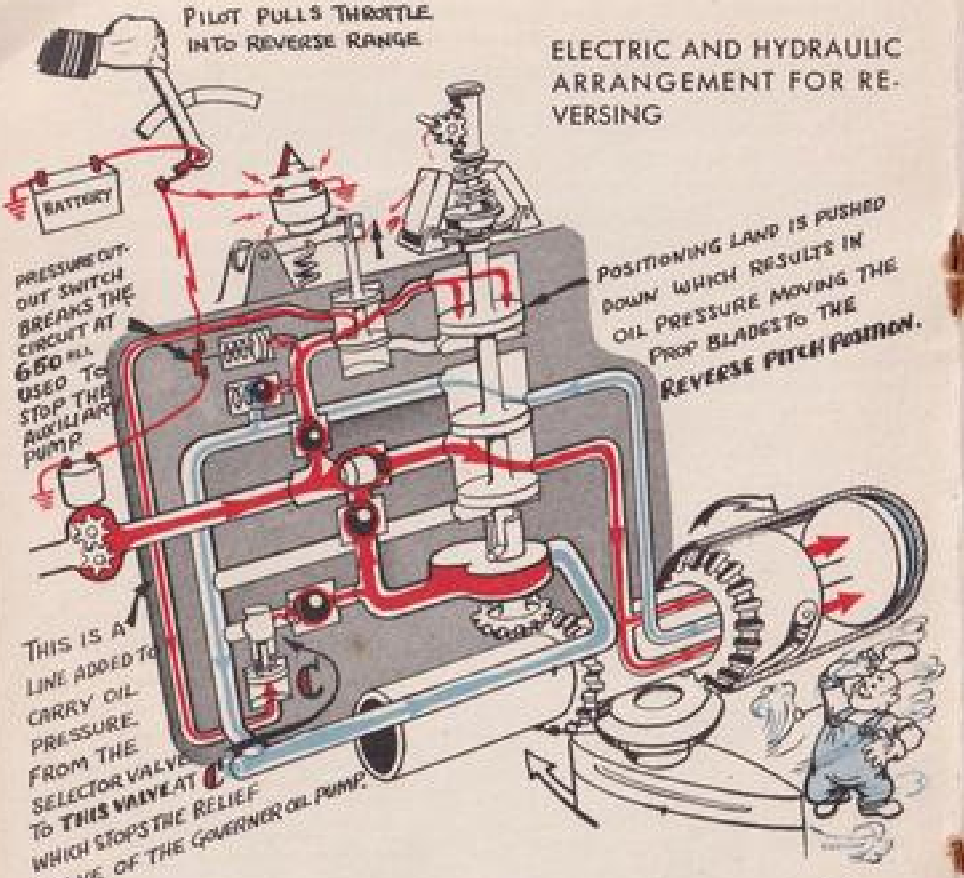
To make propeller braking by reverse thrust as natural as possible to handle, an "instinctive" throttle quadrant arrangement is provided by the majority of airframe manufacturers. All throttle positions forward of the center of the quadrant are for forward thrust operation. The rear section of the quadrant is the reverse range, and the further back the throttle is retarded, the more engine power is developed for reverse thrust. In general, the instinctive actions taken by a pilot to turn a plane to the right is to retard the right throttle and advance the left. Similarly, when the props are in reverse, appropriate reverse thrust braking power is achieved by retarding the right throttle and advancing the left.

AN AIRPLANE LANDS. THE PILOT APPLIES REVERSE THRUST. SHOULD A GUST OF WIND SWERVE THE PLANE TO THE LEFT, THE PILOT INSTINCTIVELY PULLS BACK THE RIGHT THROTTLE AND ADVANCES THE LEFT. THIS INCREASES REVERSE THRUST ON THE RIGHT SIDE WHILE DECREASING IT ON THE LEFT. THESE INSTINCTIVE MOVEMENTS BRING THE PLANE BACK TO THE DESIRED DIRECTION.

To prevent moving the throttles into the reverse quadrant during flight, locks are provided which are automatically removed when the weight of the airplane is on the landing gear.

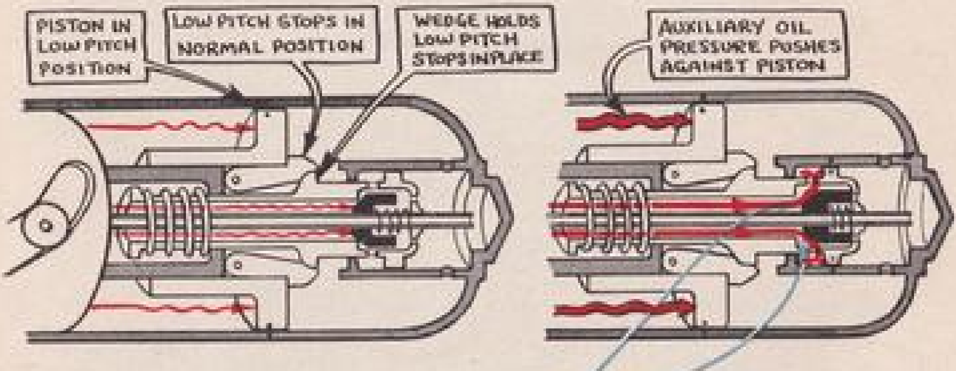

IDLE
THROTTLE
FORWARD
REVERSE
BEVEL LOCK PREVENTS THE THROTTLE FROM BEING MOVED INTO REVERSE RANGE.
SOLENOID
COMPRESSION SPRING
BATTERY
CONTACT BROKEN
PLANE IN FLIGHT. WEIGHT IS OFF LANDING GEAR.
WHEN THE SOLENOID IS ENERGIZED, IT PULLS THE BEVEL LOCK HALF OUT OF THE WAY. TO MOVE THE THROTTLE INTO OR OUT OF REVERSE REQUIRES A SLIGHT EXTRA FORCE WHICH MOVES THE BEVEL LOCK COMPLETELY OUT OF THE WAY.
BEVEL LOCK IS PULLED HALF WAY DOWN WHEN SOLENOID IS ENERGIZED
BATTERY
CONTACT MADE
PLANE ON GROUND. WEIGHT IS ON LANDING GEAR.

ELECTRIC AND HYDRAULIC ARRANGEMENT FOR REVERSING

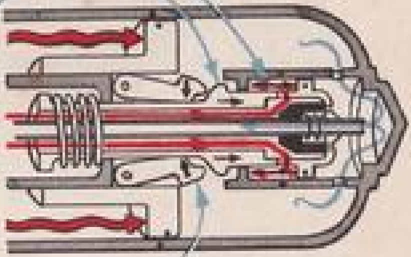

PILOT PULLS THROTTLE INTO REVERSE RANGE
BATTERY
A
PRESSURE CUT-OUT SWITCH BREAKS THE CIRCUIT AT 650 LBS. USED TO STOP THE AUXILIARY PUMP
POSITIONING LAND IS PUSHED DOWN WHICH RESULTS IN OIL PRESSURE MOVING THE PROP BLADES TO THE REVERSE PITCH POSITION.
THIS IS A LINE ADDED TO CARRY OIL PRESSURE FROM THE SELECTOR VALVE TO THIS VALVE AT C WHICH STOPS THE RELIEF VALVE OF THE GOVERNOR OIL PUMP.
C

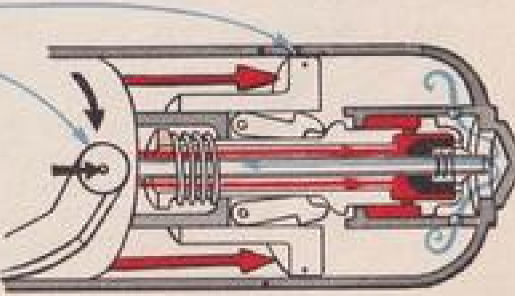
TO REVERSE THE PROP. The pilot pulls back the throttle to the idle position. When he is ready to reverse, he pulls the throttle back into the reversing part of the quadrant. This energizes the electrical circuit to the auxiliary high pressure oil pump and the solenoid selector valve at "A". The high pressure oil passes through the system and starts to reverse the prop. The selector valve at "A" lets oil flow through a line to a valve at "C", which blocks the relief valve for the governor oil pump. The governor oil pump's full output is now obtained and holds the prop in full reverse position after the auxiliary pump is stopped by the pressure cut-out switch.

To prevent inadvertent reversing during constant speed operation, Hamilton Standard incorporates mechanical, low pitch stop levers. These are hydraulically released when the propeller is reversed.

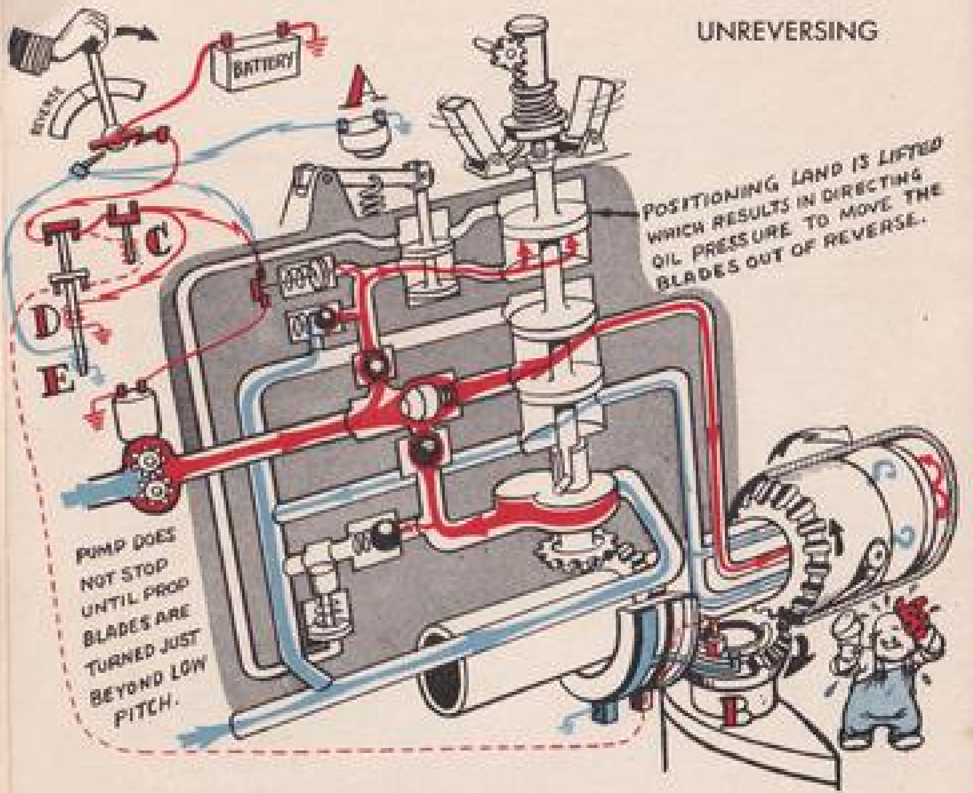

PISTON IN LOW PITCH POSITION
LOW PITCH STOPS IN NORMAL POSITION
WEDGE HOLDS LOW PITCH STOPS IN PLACE
AUXILIARY OIL PRESSURE PUSHES AGAINST PISTON

This valve opens only under auxiliary oil pump pressure. Opening this passage, the oil enters this chamber pushing this wedge forward. This wedge normally keeps the low pitch stops in position, but now the wedge has been pushed away, and the stops themselves are forced down and out of the way by the pressure of the piston against them. The piston is pushed forward by oil pressure from the auxiliary pump to the end of the slot in the cam. This is the reverse position for the prop blades.





UNREVERSING



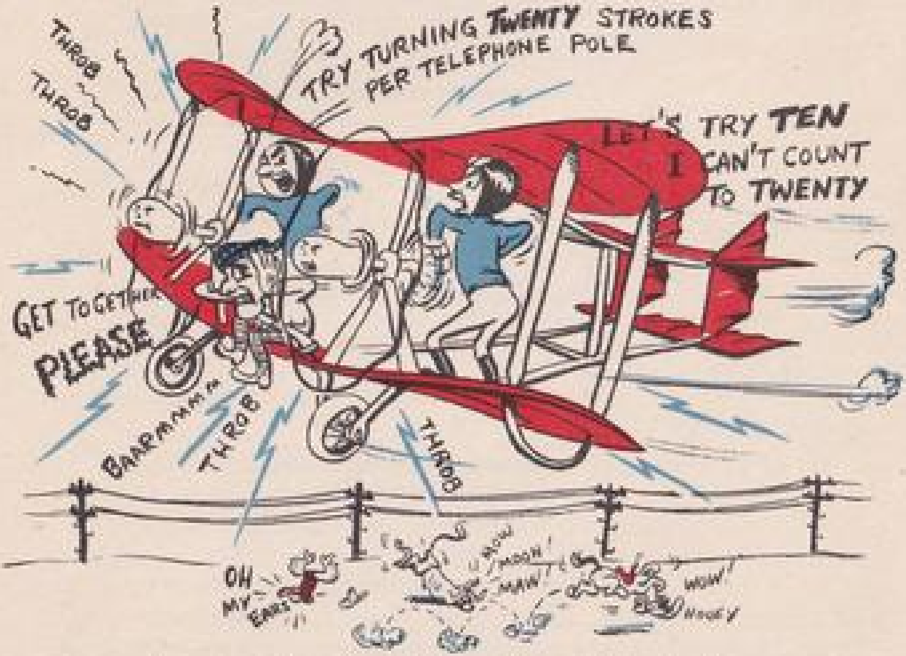
POSITIONING LAND IS LIFTED WHICH RESULTS IN DIRECTING OIL PRESSURE TO MOVE THE BLADES OUT OF REVERSE.

PUMP DOES NOT STOP UNTIL PROP BLADES ARE TURNED JUST BEYOND LOW PITCH.

TO UNREVERSE THE PROP, the pilot returns the throttle through the detent to the forward thrust position. This action de-energizes the solenoid selector valve at "A" which moves into the position shown. At the same time, the auxiliary pump is started. Its high pressure oil lifts the positioning land, allowing the oil to flow to the appropriate side of the piston. This starts the unreversing action which continues until the prop blades have turned a **few degrees beyond low pitch.** At this point, the blade butt electric contact at "B" energizes solenoid "C". This stops unreversing and allows the prop to operate in the constant speed range **to the low pitch stops.** When the throttle is again moved into reverse, solenoid "E" is energized, closing the circuit to "C", which prepares it for subsequent unreversing action.

PILOT'S MASTER CONTROL
and
SYNCHRONIZER

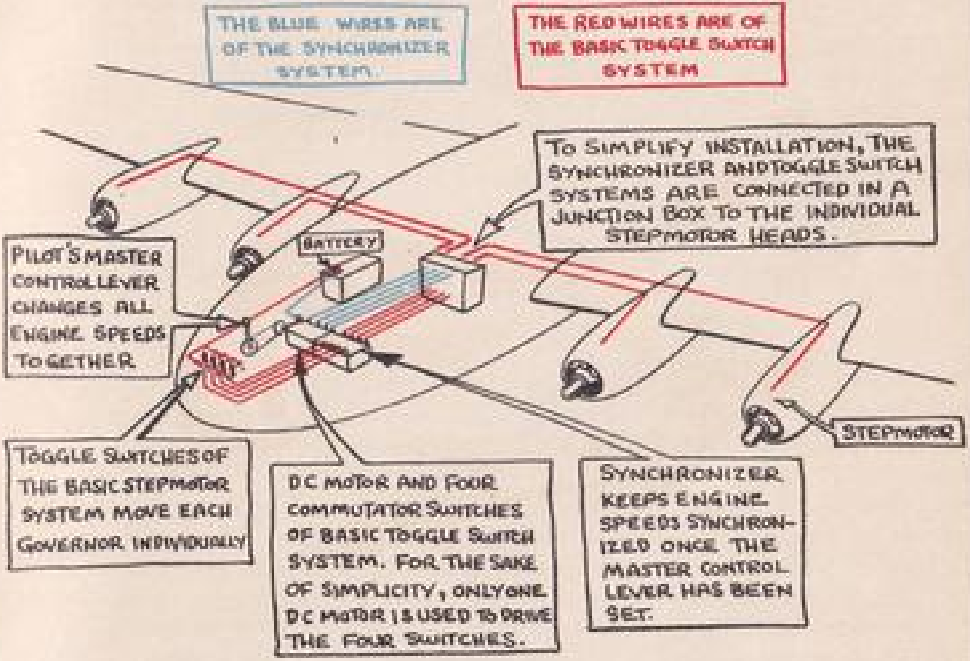
Any multi-propeller aircraft needs some method of changing the RPM of all its engines with one control, and some means of synchronizing the RPM of its propellers for passenger comfort and simplicity of pilot operation.



Any system adopted to do the job must be reliable, simple to operate, and provide safe propeller operation in case of partial or complete failure of the power source for this equipment.

To accomplish these two things, Hamilton Standard has devised a simple electric system operated by a single pilot's master control lever that changes all RPM of the engines simultaneously, and a SYNCHRONIZER that is designed to keep the RPM of all engines in complete synchronization.

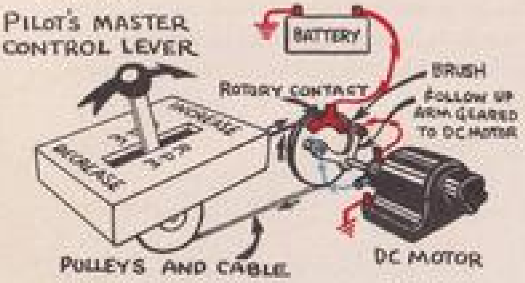
The basic electric stepmotor head system (toggle switch system) explained previously is retained, but is independent of the master control lever and synchronizing system. Both systems, however, use the same stepmotor heads at the governors.


THE BLUE WIRES ARE OF THE SYNCHRONIZER SYSTEM.
THE RED WIRES ARE OF THE BASIC TOGGLE SWITCH SYSTEM
TO SIMPLIFY INSTALLATION, THE SYNCHRONIZER AND TOGGLE SWITCH SYSTEMS ARE CONNECTED IN A JUNCTION BOX TO THE INDIVIDUAL STEPMOTOR HEADS.
BATTERY
PILOT'S MASTER CONTROL LEVER CHANGES ALL ENGINE SPEEDS TOGETHER
STEPMOTOR
TOGGLE SWITCHES OF THE BASIC STEPMOTOR SYSTEM MOVE EACH GOVERNOR INDIVIDUALLY
DC MOTOR AND FOUR COMMUTATOR SWITCHES OF BASIC TOGGLE SWITCH SYSTEM. FOR THE SAKE OF SIMPLICITY, ONLY ONE DC MOTOR IS USED TO DRIVE THE FOUR SWITCHES.
SYNCHRONIZER KEEPS ENGINE SPEEDS SYNCHRONIZED ONCE THE MASTER CONTROL LEVER HAS BEEN SET.

The basic toggle switches disconnect the pilot's master control lever and synchronizer from the electric heads and connect these heads to their own commutator switches. The pilot's master control lever and synchronizer can be turned "ON" or "OFF" at the will of the pilot without interfering with the basic toggle switch system.

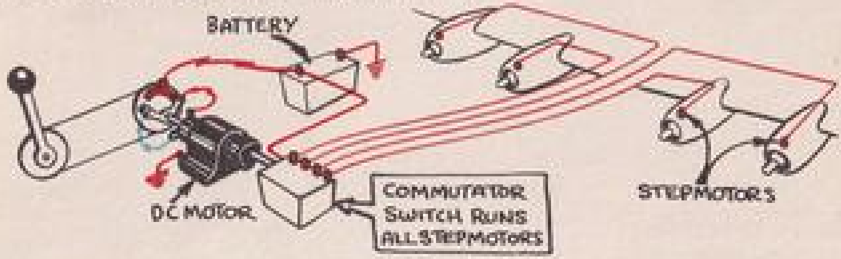
This offers the pilot two separate systems of propeller control. In addition, there is the safety feature of constant speed operation continuing automatically in case the airplane's electric power supply should fail.

The pilot's master control changes all engine speeds in the following manner:



THE MASTER CONTROL IS CONNECTED TO A ROTARY CONTACT BY A CABLE. WHEN THE CONTROL IS MOVED, THE ROTARY CONTACT TOUCHES A BRUSH OF A FOLLOW UP ARM. THIS CONNECTION STARTS A DC MOTOR TURNING IN THE DIRECTION THE MASTER CONTROL HAS BEEN MOVED. THE FOLLOW UP ARM ROTATES WITH THE DC MOTOR UNTIL ITS BRUSH MOVES OFF THE ROTARY CONTACT.

The DC motor operates a commutator switch that connects the battery to each prop governor stepmotor head.

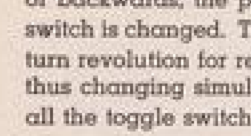


When the commutator switch is turned by the DC motor either forwards or backwards, the polarity of the battery voltages passing through the switch is changed. These voltages are sent to the stepmotor heads which turn revolution for revolution with each turn of the commutator switch, thus changing simultaneously all governor settings. It is like combining all the toggle switches of the basic stepmotor system into one lever.

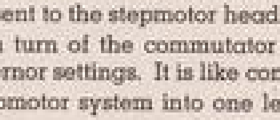
For example:

PILOT'S CONTROL SET FOR (1800RPM)

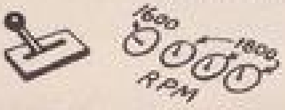
The speeds of all engines are set for 1800 RPM. The pilot wishes to increase them by 400 RPM. so he moves the lever forward until the RPM settings come to 2200.

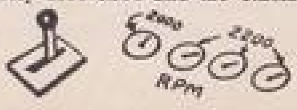


PILOT'S CONTROL MOVED TO INCREASE RPM TO 2200

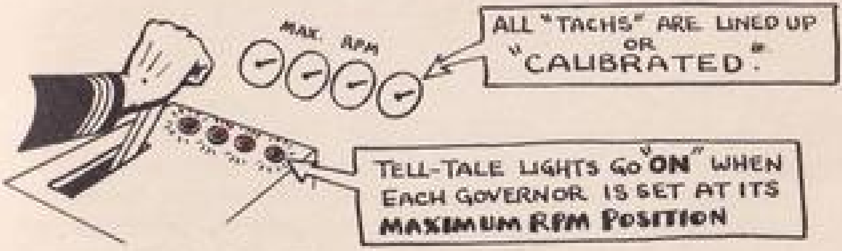


If one engine were set at 1600 RPM and the others at 1800 RPM and the pilot's control were moved to increase the speeds 400 RPM, one engine would operate at approximately 2000 RPM and the others at 2200 RPM.

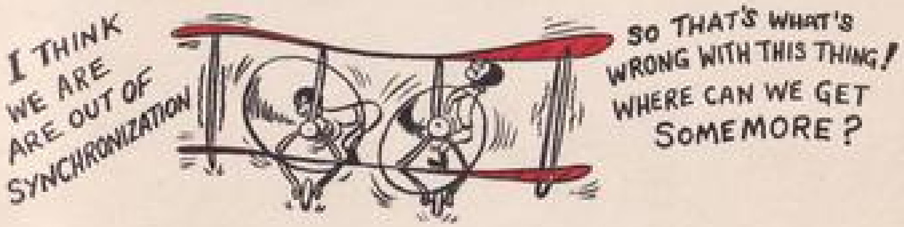




In order to "line up" all the engine speeds to the same setting, the pilot has only to push the master control to the "take-off" position. All governors will be set alike for maximum RPM. This action is called "calibrating". The pilot calibrates before each take-off. Once this has been done, the master lever can be used as an RPM position indicator.


MAX. RPM
ALL "TACHS" ARE LINED UP OR "CALIBRATED."
TELL-TALE LIGHTS GO "ON" WHEN EACH GOVERNOR IS SET AT ITS MAXIMUM RPM POSITION

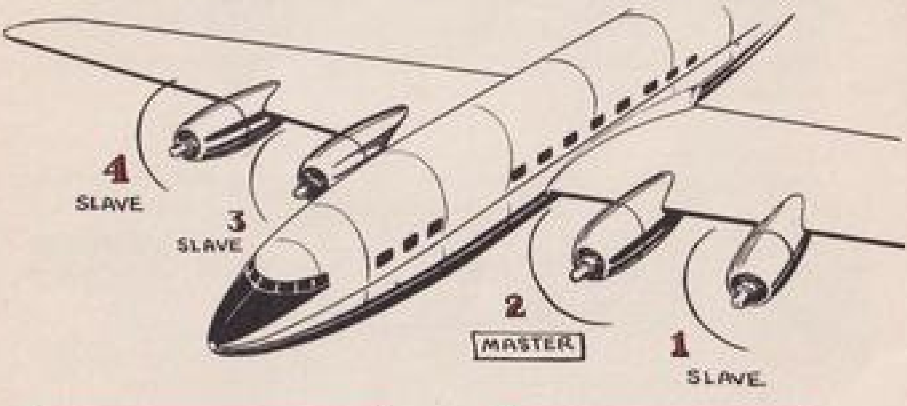
Because of the normal governor setting tolerances, the master control lever will only set the speed of the engines within a few RPM's of each other. This difference is enough to cause prop noise beats, normally referred to as "out of synchronization".


I THINK WE ARE ARE OUT OF SYNCHRONIZATION
SO THAT'S WHAT'S WRONG WITH THIS THING! WHERE CAN WE GET SOMEMORE?

The toggle switches of the basic electric system can be worked manually to take up the RPM differences of the engines and to obtain synchronization. However, this requires a considerable amount of the pilot's time. To aid the pilot, Hamilton Standard has devised a **SYNCHRONIZER.**

The synchronizer uses part of the pilot's master control equipment and is hooked up so that it can be turned "ON" or "OFF" at the will of the pilot. As a matter of fact, when the master control is being operated or is in the calibrated position, the synchronizer is automatically shut off. It is automatically turned on again once the pilot has stopped moving the master control lever and the follow up mechanism has neutralized itself at the new setting of the master control lever (except when the master control is in the calibrate position where the synchronizer is kept off).

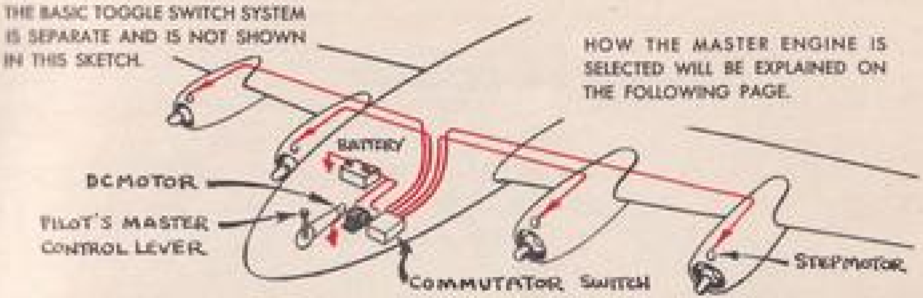
For reasons of utility and simplicity, Hamilton Standard has developed its synchronizing system so that either one of two engines may be used as a master for the other engines to follow. Thus, once the master engine's speed has been selected, the other engines act as "slaves" and synchronize their speeds to it. In case of failure of the original master engine, the pilot can switch to the alternate master engine.



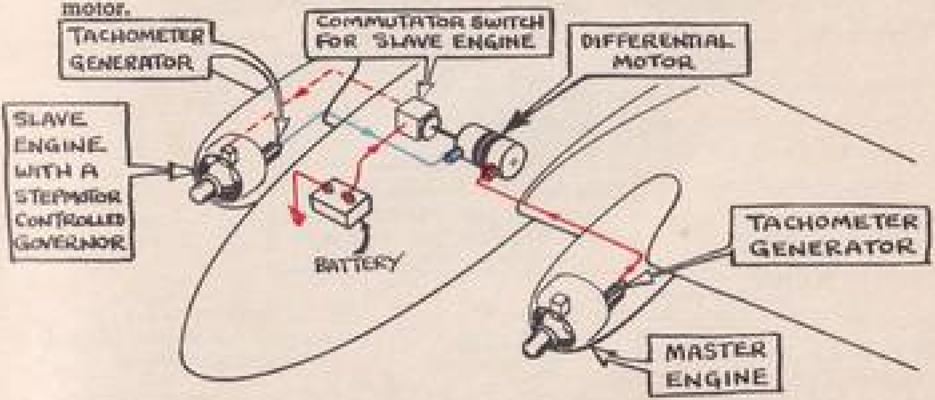
IF THE PILOT SELECTS No. 2 ENGINE AS THE MASTER, No. 1, 3 AND 4 BECOME SLAVES.

IF No. 3 IS SELECTED, No. 1, 2, AND 4 BECOME SLAVES. THE OUTBOARD ENGINES ARE ALWAYS SLAVES.

The synchronizer works like this: The pilot selects the desired engine speed with the master control lever and a master engine.

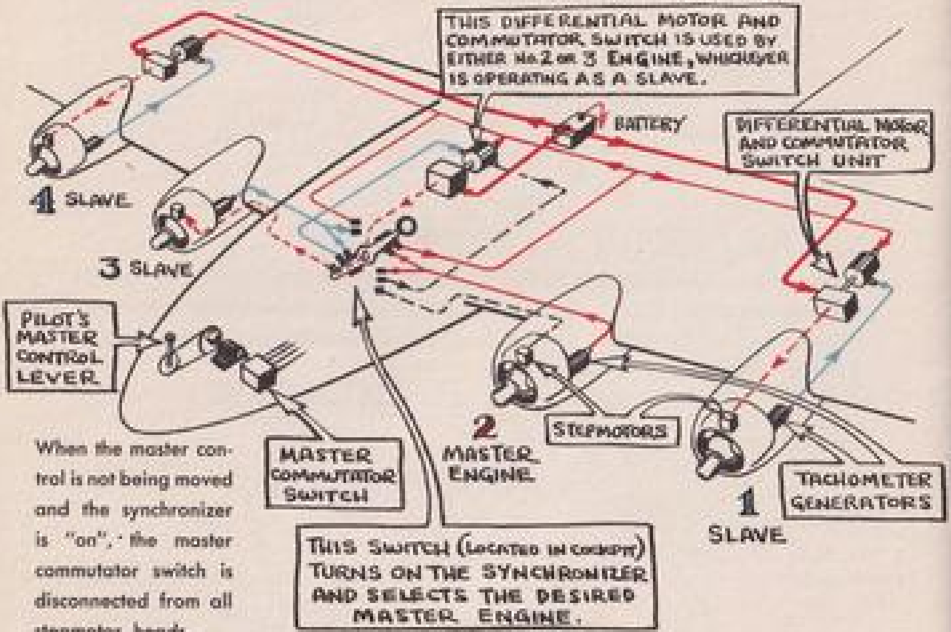

THE BASIC TOGGLE SWITCH SYSTEM IS SEPARATE AND IS NOT SHOWN IN THIS SKETCH.
HOW THE MASTER ENGINE IS SELECTED WILL BE EXPLAINED ON THE FOLLOWING PAGE.
BATTERY
DC MOTOR
PILOT'S MASTER CONTROL LEVER
COMMUTATOR SWITCH
STEPMOTOR

This master engine drives a small **electric generator** hooked up to its **tachometer drive.** The frequency of this generator varies with the speed of the engine. Its output is connected to **one winding** of a **differential motor.**

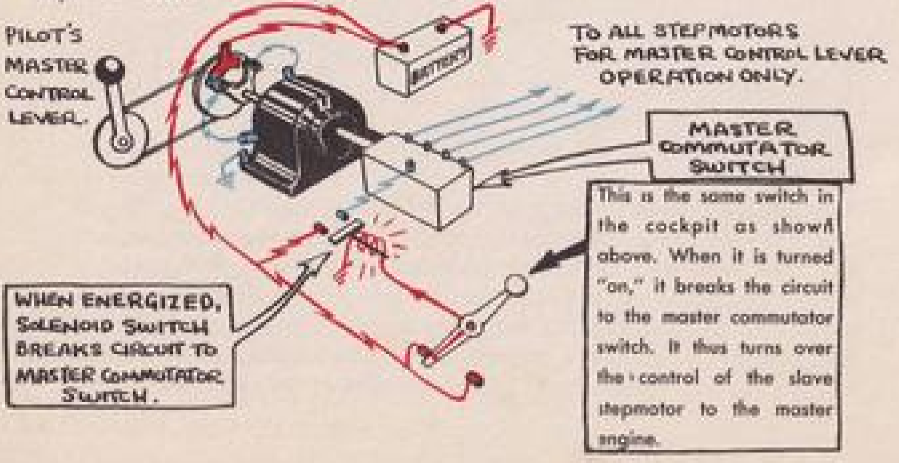

TACHOMETER GENERATOR
COMMUTATOR SWITCH FOR SLAVE ENGINE
DIFFERENTIAL MOTOR
SLAVE ENGINE WITH A STEPMOTOR CONTROLLED GOVERNOR
BATTERY
TACHOMETER GENERATOR
MASTER ENGINE

The **other winding** of this differential motor is wired to another tachometer generator driven by a "**slave engine**". If the slave engine is turning at a different speed from the master, the differential motor will turn in the direction of the greater of the two frequencies coming into the motor from the tachometer generators. The differential motor is geared to a **commutator switch** for the **slave engine.** When the switch is rotated, the stepmotor on the slave engine is energized and resets the governor. When the slave engine's speed is the same as the master, the differential motor stops. **Synchronization is accomplished in this manner.**

To provide synchronization on an aircraft powered by more than two engines, it is only necessary to add a commutator switch, differential motor, tachometer generator and stepmotor head to each additional engine and connect these to the differential motor of the master engine's tachometer generator.

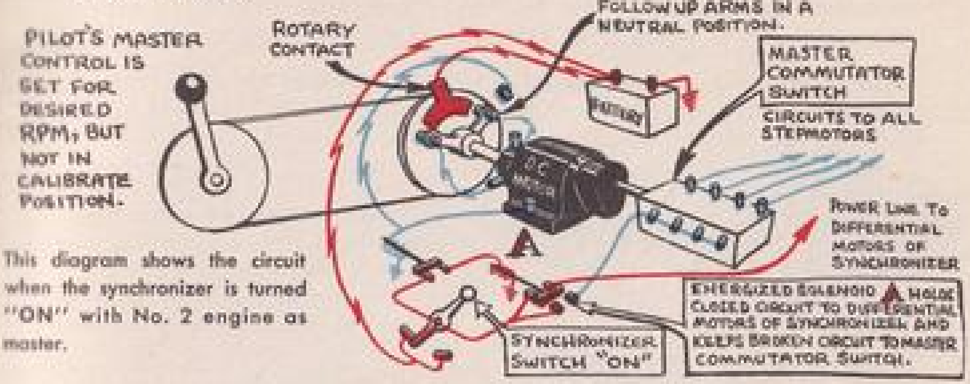

THIS DIFFERENTIAL MOTOR AND COMMUTATOR SWITCH IS USED BY EITHER No 2 OR 3 ENGINE, WHICHEVER IS OPERATING AS A SLAVE.
BATTERY
DIFFERENTIAL MOTOR AND COMMUTATOR SWITCH UNIT
4 SLAVE
3 SLAVE
PILOT'S MASTER CONTROL LEVER
2 MASTER ENGINE
STEPMOTORS
MASTER COMMUTATOR SWITCH
TACHOMETER GENERATORS
1 SLAVE
THIS SWITCH (LOCATED IN COCKPIT) TURNS ON THE SYNCHRONIZER AND SELECTS THE DESIRED MASTER ENGINE.

When the master control is not being moved and the synchronizer is "on", the master commutator switch is disconnected from all stepmotor heads.

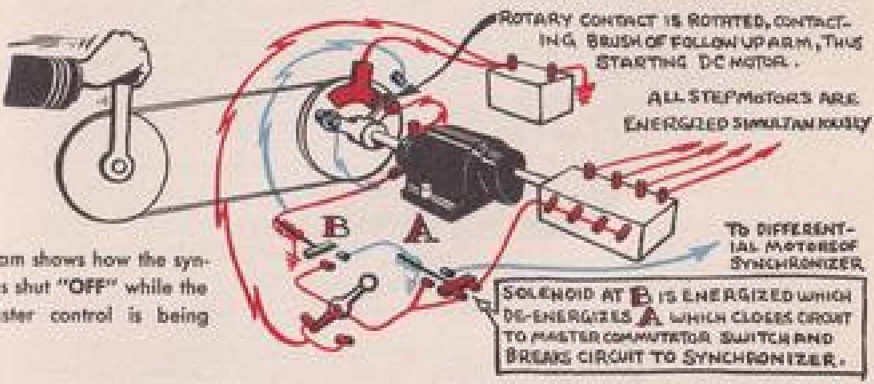

PILOT'S MASTER CONTROL LEVER
BATTERY
TO ALL STEPMOTORS FOR MASTER CONTROL LEVER OPERATION ONLY.
MASTER COMMUTATOR SWITCH
WHEN ENERGIZED, SOLENOID SWITCH BREAKS CIRCUIT TO MASTER COMMUTATOR SWITCH.

This is the same switch in the cockpit as shown above. When it is turned "on," it breaks the circuit to the master commutator switch. It thus turns over the control of the slave stepmotor to the master engine.

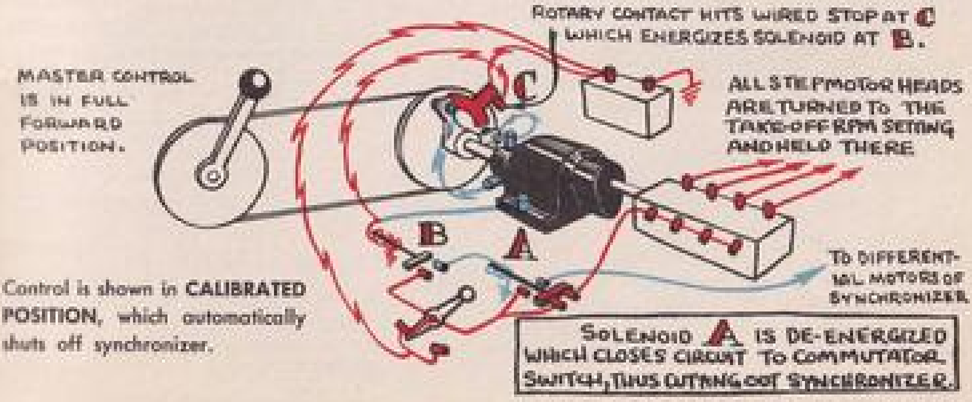
The following sketches demonstrate how the pilot's master control shuts "OFF" the synchronizer whenever it is being moved, or is in the calibrated position.


PILOT'S MASTER CONTROL IS SET FOR DESIRED RPM, BUT NOT IN CALIBRATE POSITION.
ROTARY CONTACT
FOLLOW UP ARMS IN A NEUTRAL POSITION.
BATTERY
MASTER COMMUTATOR SWITCH
CIRCUITS TO ALL STEPMOTORS
D.C. MOTOR
A
POWER LINE TO DIFFERENTIAL MOTORS OF SYNCHRONIZER
ENERGIZED SOLENOID A HOLDS CLOSED CIRCUIT TO DIFFERENTIAL MOTORS OF SYNCHRONIZER AND KEEPS BROKEN CIRCUIT TO MASTER COMMUTATOR SWITCH.
SYNCHRONIZER SWITCH "ON"

This diagram shows the circuit when the synchronizer is turned "ON" with No. 2 engine as master.


ROTARY CONTACT IS ROTATED, CONTACTING BRUSH OF FOLLOW UP ARM, THUS STARTING DC MOTOR.
ALL STEPMOTORS ARE ENERGIZED SIMULTANEOUSLY
B
A
TO DIFFERENTIAL MOTORS OF SYNCHRONIZER
SOLENOID AT B IS ENERGIZED WHICH DE-ENERGIZES A WHICH CLOSES CIRCUIT TO MASTER COMMUTATOR SWITCH AND BREAKS CIRCUIT TO SYNCHRONIZER.

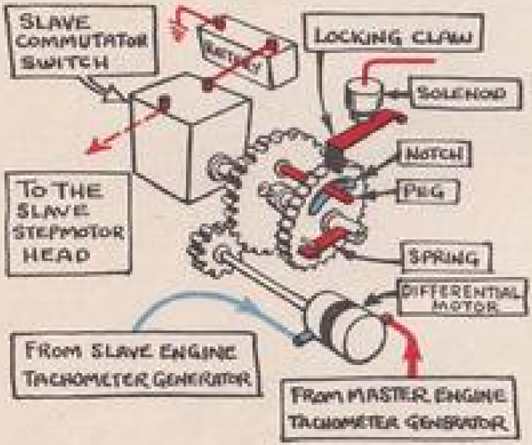
This diagram shows how the synchronizer is shut "OFF" while the pilot's master control is being moved.


ROTARY CONTACT HITS WIRED STOP AT C WHICH ENERGIZES SOLENOID AT B.
MASTER CONTROL IS IN FULL FORWARD POSITION.
C
ALL STEPMOTOR HEADS ARE TURNED TO THE TAKE-OFF RPM SETTING AND HELD THERE
B
A
TO DIFFERENTIAL MOTORS OF SYNCHRONIZER
SOLENOID A IS DE-ENERGIZED WHICH CLOSES CIRCUIT TO COMMUTATOR SWITCH, THUS CUTTING OUT SYNCHRONIZER.

Control is shown in **CALIBRATED POSITION**, which automatically shuts off synchronizer.

In the system just described, if the master engine should fail, it would drag down the speed of the slaves. To prevent this, a safety device is incorporated which limits the amount of control the master has over the slaves. It is called **THE LIMITED BAND FEATURE.**

This mechanical limiting device is inserted between the commutator switch and differential motor of each slave engine.

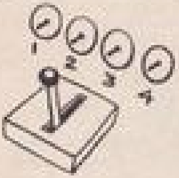

SLAVE COMMUTATOR SWITCH
RELAY
LOCKING CLAW
SOLENOID
NOTCH
PEG
SPRING
DIFFERENTIAL MOTOR
TO THE SLAVE STEPMOTOR HEAD
FROM SLAVE ENGINE TACHOMETER GENERATOR
FROM MASTER ENGINE TACHOMETER GENERATOR

The notch and peg restrict the differential motor from turning either way more than ± 3% of the RPM of the slave engine involved. In order to turn beyond this limit, the locking claw has to be lifted.

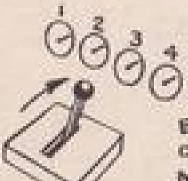
Whenever the master pilot's control lever moves, it energizes the solenoid that lifts the locking claw. This permits unlimited rotation of the slave commutator switch.

The spring recenters the notch and peg to re-establish the ± 3% limited band feature when the master control has stopped moving.

THIS SHOWS HOW SLAVE ENGINES FOLLOW THE MOVEMENTS OF THE PILOT'S MASTER CONTROL LEVER.

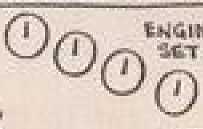


MASTER ENGINE AND SLAVES SET FOR **LOW RPM**



ENGINE SPEED INCREASED ON ALL ENGINES BY MOVING MASTER LEVER FORWARD.

THIS SHOWS HOW THE SLAVE ENGINES FOLLOW THE MASTER FOR ONLY ±3% OF THEIR SPEED WHEN UNDER SYNCHRONIZER CONTROL.



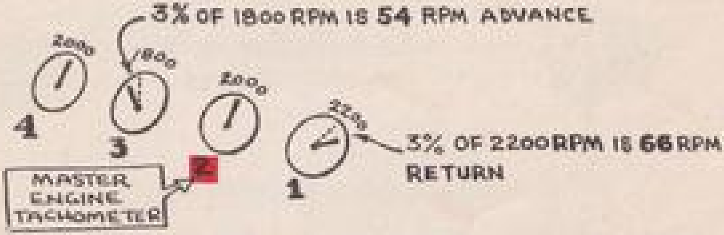
ENGINE SPEEDS SET AT 2550 RPM.

±3% OR 77 RPM IS ONLY LOSS IN SLAVE ENGINE SPEED.

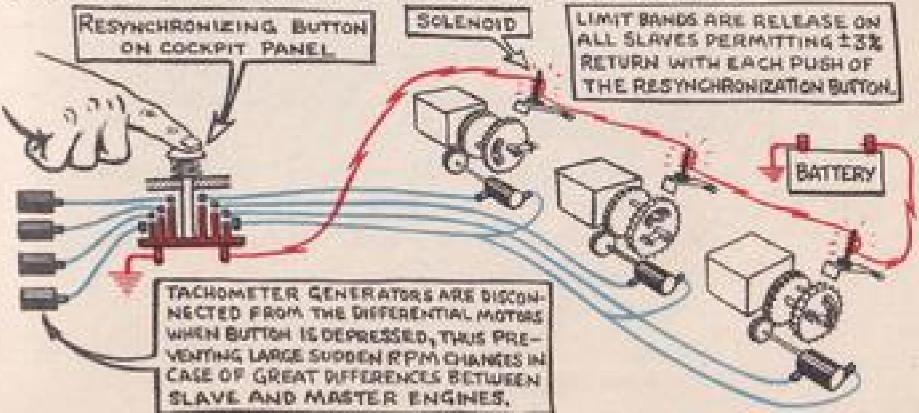
MASTER ENGINE SPEED REDUCED BY TOGGLING OR ENGINE FAILURE

Because of the **limited band feature,** the master engine can only control the speed of the slaves for synchronizing by ± 3%.

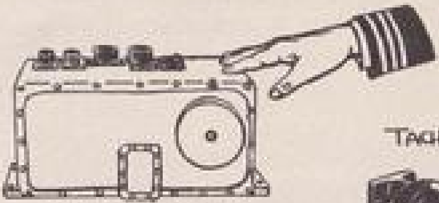
Let's take an example. The master engine is set at 2000 RPM. One slave is at 1800 RPM and another is at 2200 RPM. The synchronizer is turned on. The speeds of the slaves move toward the master only as far as their limiting bands will permit, which will be ±3% of their speeds.

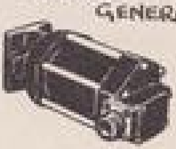

3% OF 1800 RPM IS 54 RPM ADVANCE
2000
1800
2000
2200
4
3
2
1
MASTER ENGINE TACHOMETER
3% OF 2200 RPM IS 66 RPM RETURN

Normally, the speeds of the slaves can be brought within the master engine's range by working the toggle switches of the stray slaves. This requires close attention by the pilot. To make it easier, a **RESYNCHRONIZING BUTTON** is provided. When pushed by the pilot, it energizes the solenoids that lift the locking claws from the limited-band devices and breaks the circuit from the tachometer generators to the differential motors. The limited-bands, thus relieved, recenter themselves. The pilot then must release the synchronizing button in order to permit the differential motors to change the RPM of the slaves by another ±3%. The pilot repeats this action until all the engines are synchronized.

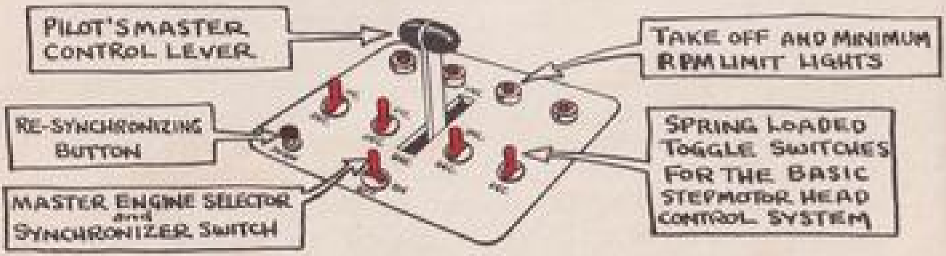

RESYNCHRONIZING BUTTON ON COCKPIT PANEL
SOLENOID
LIMIT BANDS ARE RELEASE ON ALL SLAVES PERMITTING ±3% RETURN WITH EACH PUSH OF THE RESYNCHRONIZATION BUTTON.
BATTERY
TACHOMETER GENERATORS ARE DISCONNECTED FROM THE DIFFERENTIAL MOTORS WHEN BUTTON IS DEPRESSED, THUS PREVENTING LARGE SUDDEN RPM CHANGES IN CASE OF GREAT DIFFERENCES BETWEEN SLAVE AND MASTER ENGINES.

This propeller control equipment, such as the differential motors and commutator switches for the slave engines, the DC motor and its master commutator switch, and the toggle switch DC motor and its commutating switches, is contained in a compact box.





PILOT'S PROP CONTROL PANEL


PILOT'S MASTER CONTROL LEVER
TAKE OFF AND MINIMUM RPM LIMIT LIGHTS
RE-SYNCHRONIZING BUTTON
SPRING LOADED TOGGLE SWITCHES FOR THE BASIC STEPMOTOR HEAD CONTROL SYSTEM
MASTER ENGINE SELECTOR and SYNCHRONIZER SWITCH

Features of the Master Control and Synchronizer System.

1. Control of all engines by one lever.
2. Control of individual engines by toggle switches whether synchronizer is "ON" or "OFF".
3. All engines automatically calibrated but independent of one another at take-off RPM setting.
4. Limited control of the master engine over the slaves when synchronizer is "ON".
5. Alternate selection of master engine.
6. Continuous constant speed operation of propellers even if electric system should fail.

ELECTRIC DE-ICING

Ice formations on a propeller can set up very fatiguing vibrations for both passengers and aircraft. The discharge of large pieces of ice from a prop can materially damage an aircraft structure adjacent to the props.

To remove ice from a prop under these conditions it is necessary to do so evenly and in small pieces.

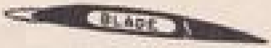
To provide an unlimited supply of proper de-icing activity during all operations, Hamilton Standard — after thorough research — selected thermal de-icing for prop blades by utilizing electricity generated by the aircraft engines.

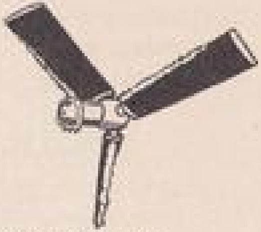
Tests show that the effect of ice on aerodynamic efficiency of the propeller is small in comparison with these other conditions.

AH!

TYPES OF ICE FORMATION ENCOUNTERED on propellers is similar to that found on airplane wings.

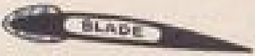
"Rime" Ice –

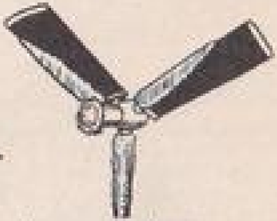




This ice builds outward and along the leading edge of the blade to approximately ⅔ of its length. Centrifugal force prevents it from forming beyond this point. It usually forms at temperatures below 15°F in turbulent clouds and at any freezing temperatures in non-turbulent clouds.

"Glaze" or Clear Ice –

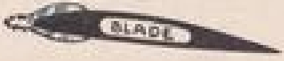


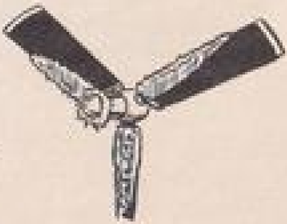


Glaze ice results from the freezing of large cloud droplets or rain drops which do not freeze immediately upon contact with the blade, but form a thin sheet of water which eventually freezes. This process repeats itself until the formation can seriously upset the balance of the propeller.

Glaze ice usually forms in the turbulent clouds at moderate freezing temperatures or in rough air at very low temperatures.

"Glime" Ice –

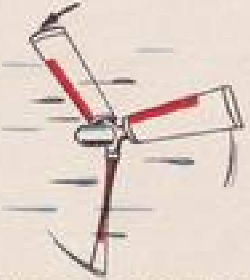




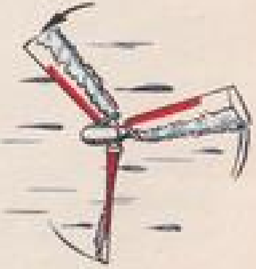
This is a combination of Glaze and Rime formations.

Hamilton Standard designed its de-icing equipment around the **principle of removing, not preventing, ice.** Since ice builds up primarily on the leading edge of the blade, de-icing activity must be applied to that area.

If the leading edge were kept heated continuously to **prevent ice from forming,** instead of freezing, water would flow out to the blade tip and back across its width to the trailing edge, freezing as it went over the unheated part of the blades. Thus, the entire blade would have to be heated, adding materially to the amount of power and equipment required.

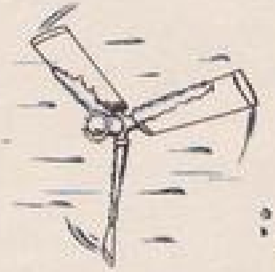


HOT EDGE PREVENTS ICE FROM FORMING AT LEADING EDGE

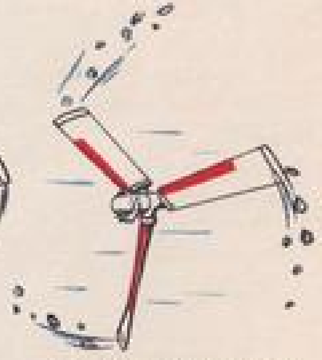


WATER FLOWS BACK TO UNHEATED BLADE AREAS AND FREEZES

However, **when ice has already formed on a whirling blade,** only enough heat is required to melt the thin layer that holds the mass of ice to the blade. Once this is loosened, **centrifugal force removes** the unmelted outer mass. Then, the heat can be shut off, and ice again allowed to form on the leading edge of the propeller. **The removal process is repeated.**

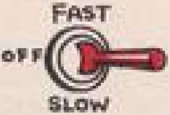


ICE IS ALLOWED TO ACCUMULATE



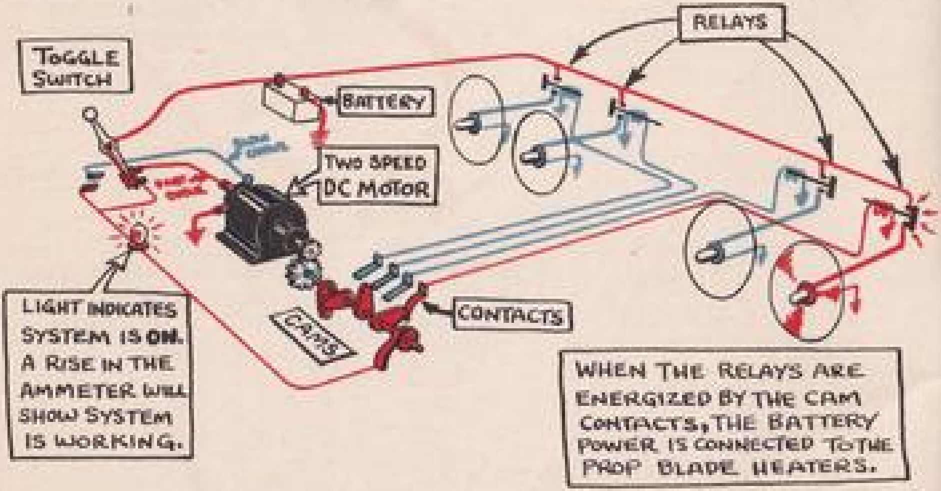
HEAT IS TURNED ON. CENTRIFUGAL FORCE THROWS ICE OFF.

Hamilton Standard's system provides **two cycles** for alternately applying heat and shutting it off. There is a cycle for **"heavy, rapid-forming ice"** — 20 seconds on and 60 seconds off — and a slower cycle for **"lighter, slower-forming ice** — 60 seconds on and 180 seconds off. Either cycle may be selected by the pilot by flipping a toggle switch in the cockpit, centered for the "OFF" position, up for the "FAST" cycle, and down for the "SLOW" cycle.



TOGGLE SWITCH IN COCKPIT.

The equipment that automatically runs the cycle selected is contained in one box. It consists of a simple, two-speed DC motor that turns **four cams** mounted on the same shaft.


RELAYS
TOGGLE SWITCH
BATTERY
TWO SPEED DC MOTOR
CAMS
CONTACTS
LIGHT INDICATES SYSTEM IS ON. A RISE IN THE AMMETER WILL SHOW SYSTEM IS WORKING.
WHEN THE RELAYS ARE ENERGIZED BY THE CAM CONTACTS, THE BATTERY POWER IS CONNECTED TO THE PROP BLADE HEATERS.

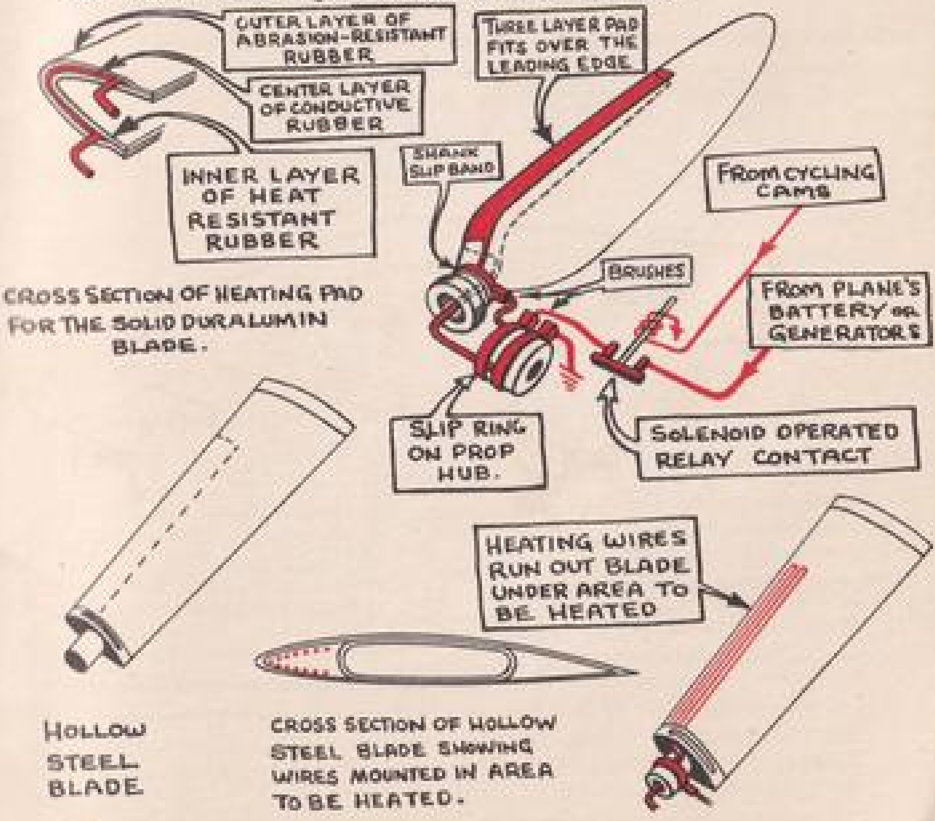
The cams are arranged so that only **one prop is heated at a time,** thus minimizing the load on the plane's electrical system.

In order to reduce high power wires to a minimum, relays operated by the cycling equipment connect the battery with the prop blade heaters. The cycling equipment uses only low power wires.

Power for de-icing is transferred from the plane's battery to the prop blades through the slip ring and slip band assemblies used in the unfeathering and unreversing systems. The de-icing system functions through the entire blade angle range of the prop.

Electric de-icing is provided on both the solid duralumin and hollow steel blades.

The duralumin blade is fitted with a thin rubber pad containing the heating element. This is sandwiched between an inner layer of heat-resistant rubber and an outer layer of abrasion-resistant rubber. The hollow steel blade has heating wires mounted inside the blade.


OUTER LAYER OF ABRASION-RESISTANT RUBBER
THREE LAYER PAD FITS OVER THE LEADING EDGE
CENTER LAYER OF CONDUCTIVE RUBBER
INNER LAYER OF HEAT RESISTANT RUBBER
SHANK SLIP BAND
FROM CYCLING CAMS
BRUSHES
FROM PLANE'S BATTERY OR GENERATORS
SLIP RING ON PROP HUB.
SOLENOID OPERATED RELAY CONTACT
HEATING WIRES RUN OUT BLADE UNDER AREA TO BE HEATED

CROSS SECTION OF HEATING PAD FOR THE SOLID DURALUMIN BLADE.

HOLLOW STEEL BLADE

CROSS SECTION OF HOLLOW STEEL BLADE SHOWING WIRES MOUNTED IN AREA TO BE HEATED.

PROPELLER OPERATION

PRE-FLIGHT

Starting Check

1. Turn off the synchronizer.
2. Set props in take-off (low pitch) position to allow engine to turn over with as little air load as possible.
3. Check tell-tale lights for indication of governor position.
4. Start engines.

Decrease RPM Governor Check (with synchronizer off).

1. Use throttles to set engine speed at 1500 RPM.
2. Move all toggle switches to the **decrease RPM position.**
3. Check each tell-tale light.
4. Compare time it takes each head to travel from take-off to minimum RPM with other heads (tell-tale lights go out and come on again). The difference should not be more than 5 seconds.

Increase RPM Governor Check

1. Move toggle switches to **increase RPM position.**
2. Return toggle switches to neutral position after each engine speed has been increased by 200 RPM.
3. Check tell-tale lights are out.

Calibration Check

1. Turn synchronizer **"ON"** (master lever is in take-off position).
2. Pull the master lever back a few inches.
3. Reset lever in take-off position.
4. Check tell-tale lights are **on.** This indicates all governors are in the take-off or calibrate position.

Feathering Check

1. Governors in take-off RPM position.
2. Use throttles to set engine speed for approximately 1500 RPM.
3. Depress momentarily each feathering button.
4. When engine speed is reduced to 1000 RPM, **pull buttons back** to neutral. It is not advisable to feather the props completely as the resulting propeller air loads might foul-up and stall the engines.

(These five checks can be made during the engine warm up period. By the time they have been completed, the propeller has been exercised sufficiently to circulate any cold oil from the system, replacing it with warm engine oil.)

PRE-TAKE-OFF

Reversing Check

1. Set props for take-off (check tell-tale lights).
2. Pull throttles back through idle into reverse idle range of quadrant.
3. Check timing of all props by watching for momentary increase in all RPM's as props go through flat pitch. All props should reverse within 1 second of each other.
4. Look for reverse thrust indications by direction of exhaust smoke, dirt and dust movements on ramp.
5. Do not operate props in reverse thrust for a long period of time due to the adverse heating effect on the ignition harnesses of the engines.

Unreversing Check.

1. Move throttles forward through the detent into the forward thrust section of the quadrant.
2. Check timing of all props by noting momentary increase in all RPM's as props go through flat pitch. All props should unreverse within one second of each other.

Master Lever and Synchronizer Check

1. Place master lever in take-off position (check tell-tale lights).
2. Set engine speeds at approximately 2150 RPM, after completing all engine magneto and blower checks.
3. Turn on the synchronizer. (If this check is being made on a four-engine airplane and it is only practical to run two engines at a time at 2150 RPM, run them up on the same side. Turn the synchronizer "ON" to select the master engine on that side. Repeat the following check on the other two engines. If all four engines are run at one time, both master engines should be checked.)
4. Decrease engine speed to 2000 RPM by moving master lever.
5. Hold master lever in the 2000 RPM position until synchronizer has trimmed up the tachometers.
6. Return master lever to take-off position.
7. Check tell-tale lights.

EMERGENCY AND PRACTICE FEATHERING PROCEDURE.

1. Definitely determine which nacelle is malfunctioning. If the trouble is severe overspeeding, immediately reduce airplane speed.
2. Close the throttle completely and press the feathering button.
3. Shut down the nacelle.
    a. Put the mixture control in **Idle Cut-Off.**
    b. Shut off the fuel booster pump.
    c. Shut off the fuel supply.
    d. Turn off the ignition switch after the prop has stopped rotating.
    e. Turn off the generator switch for the dead engine.
    f. Move the governor control to the **minimum RPM position.**

Note

While practicing feathering, keep to a minimum the time the prop is left in the feathered position to avoid excessive oil cooling in the lower cylinders and possible hydraulic lock when unfeathering.

Unfeathering Check

Caution should be taken when unfeathering a propeller feathered because of a malfunctioning engine. Returning the engine to operation may result in further damage.

1. Hold the toggle switch for the engine to be unfeathered in the minimum RPM position until the tell-tale light goes on.
2. Pull out the unfeathering button for **two seconds.**
3. Check the prop and tach for windmilling. (At very cold oil temperatures it may be necessary to repeat Step No. 2 in order to start the prop windmilling.) Once the prop starts to windmill, the governor will take over control of the prop and position it at the minimum RPM setting of the governor. If the prop should start to windmill but fail to speed up to the setting for the governor, again pull out the unfeathering button for **one second. Wait 10 seconds** for prop action, and repeat this action, if necessary, until the RPM starts increasing toward the governor setting.
4. Turn on the ignition switch after the prop has unfeathered.
5. Turn on the fuel supply and fuel booster pump.
6. Set mixture control in AUTO RICH.
7. Open throttle for low manifold pressure setting.
8. Turn on engine's generator.
9. Allow engine to warm up before going to high powers.

Electric De-icing Procedure

When an icing condition is encountered and there are indications of ice forming on the prop:

1. Flip switch to fast cycle (indicator light goes on).
2. Observe ammeter for indication that system is functioning.
3. Flip switch to slow cycle, if there are no indications that ice is being removed.
4. Select cycle that gives best results.

Note: As both cycles require the same amount of power to operate, the pilot may select either without increasing the load on the electrical system.

Electric De-icing Check.

1. Select engine speed to operate all generators.
2. Turn de-icing switch to SLOW cycle (indicator light goes on).
3. Observe ohmmeter reading (see chart below).
4. Turn de-icing switch to FAST cycle (indicator light goes on).
5. Observe ammeter reading (see chart below).
6. Return switch to OFF position (indicator light goes out). Ammeter reading returns to normal.

Note: The light indicates the de-icing system is turned on. The ammeter readings show that the system is working.

Type of Aircraft	Slow Cycle		Fast Cycle	
	Cycle On Ammeter shows increase for:	Cycle Off Ammeter normal for:	Cycle On Ammeter shows increase for:	Cycle Off Ammeter normal for:
Single-engine	60 sec.	180 sec.	20 sec.	60 sec.
Two-engine	60 sec.	60 sec.	20 sec.	20 sec.
Four-engine	60 sec.	Momentary drop in ammeter	20 sec.	Momentary drop in ammeter

Note: A deviation of ±10% is allowed from these values.

PROP TO PILOT

HAMILTON STANDARD
PROPELLERS

A HANDBOOK FOR PILOTS

on the

CONSTANT SPEED — FEATHERING

REVERSING — SYNCHRONIZING — ELECTRIC DE-ICING

HAMILTON STANDARD HYDROMATIC PROPELLER